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A Summary of Current Program, 4/1/64

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and Preliminary Report of Progress

for 4/1/63 to 3/31/64

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CURRENT SERIAL RECORDS

AGRICULTURAL ENGINEERING RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

and related work of the

STATE AGRICULTURAL EXPERIMENT STATIONS

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued between April 1, 1963, and March 31, 1964. Current agricultural research findings are also published in the monthly U.S.D.A. publication, Agricultural Research. This progress report was compiled in the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland.

UNITED STATES DEPARTMENT OF AGRICULTURE  
Washington, D. C.  
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## INTRODUCTION

Agricultural Engineering Research as used in this report is concerned with the applications of engineering principles to agricultural production and rural living. More specifically, it deals with the power, machines and structures required, and includes (a) development of new and improved equipment for the more effective mechanization of seedbed preparation, fertilization, planting, cultivation, pesticide application, harvesting and farm handling of crops, and studies of the more efficient use of such equipment; (b) development of more effective and lower cost buildings and equipment for the handling and sheltering of livestock, including research in functional requirements; for the handling and storing of farm commodities on the farm, and for farm living; (c) development of more effective methods and equipment for the mechanical preparation and conditioning of farm products for farm use or sale, including such testing and quality determination as needed to adequately evaluate research results, and (d) adaptation and development of methods and equipment for effective and economical farm and rural applications of electric energy, used as power, heat, light and other electromagnetic radiations for plant and animal production, farm processing and rural living.

The importance of Agricultural Engineering research to the nation's agriculture is shown by the fact that power, machines and structures with which it is concerned are essential facilities for every one of more than 3.5 million farms on which equipment and buildings valued at over 45 billion dollars are used to produce and handle about 600 million tons of crop and animal products each year. Also, the solutions of most plant and animal production problems are in part determined by the machines and structures available and likewise almost every new finding in soil, plant, or animal science research requires additional engineering research for its most effective implementation. As the relative cost of labor increases and the mechanization of agricultural operations progresses, engineering research becomes increasingly important. Since the close of World War II the annual man-hours of farm labor has been reduced nearly one-half, from 17.4 billion to 8.8 billion, the number of tractors has about doubled, from about 2.5 million to 4.7 million, and the percent of farms served by electric power lines has also doubled from about 48 to over 98. Each farm worker has available between 30 and 40 mechanical and electric horsepower. The investment per worker for land and other facilities, which is higher than for all manufacturing, averages over \$25,000. For many commercial farms it is more than twice as great and for certain types of farms over large areas it is \$100,000 or more.

The following examples are illustrative of research accomplishments for which the Agricultural Engineering Research Division (AERD) has had a major responsibility:

(1) Determining the effects of plow size and type on performance in different soil types and conditions; the effects of tire characteristics such as cord arrangement, tread design, rim width and diameter, and inflation pressure on the performance of traction tires on different soil types and field conditions; and the effects of methods of manufacture and steel specifications on the service of disks used on agricultural implements. The determinations are being used by the farm equipment industry and technical advisors to farmers as well as directly by farmers.

(2) Agricultural engineering research has made possible the effective ginning of the machine and rough hand-harvested seed cotton. The developments of this research program have been a primary factor in maintaining the competitive position of cotton.

(3) In cooperation with several State Experiment Stations, good progress has been made in mechanizing the harvesting and farm handling of several fruit crops, including cherries, blueberries, prunes, and dates. This is particularly true for tart cherries where labor requirements have been reduced by 75 percent and costs by 50 percent.

(4) Ventilation of livestock buildings--Research in cooperation with State Experiment Stations has obtained much needed basic data on the heat and moisture given off by cattle, hogs, and poultry, and on the influence of building environment on production and feed consumption. The heat and moisture dissipation data are considered basic design data for ventilation systems of poultry, dairy, and swine buildings. They appear in design handbooks including the 1964 Guide and Data Book of the American Society of Heating, Refrigeration, Ventilating, and Air Conditioning Engineers, and are used by makers of ventilating equipment, prefabricated buildings and package buildings as well as by specialists advising farmers on their own construction. Building improvements resulting from the above research have contributed to the substantial rise in efficiency of livestock production that has occurred during the past decade.

(5) Research on light traps for insects, pioneered by AERD, has developed this device as a very effective means for detection and estimation of insect infestation. This development has aided quarantine activities and the planning of chemical control operations. More than 700 electric traps are in use to determine emergence and migration of the pink bollworm moth in the Southeast and the European chafer in the Northeast and thus facilitate more efficient use of chemical controls. An additional 400-500 traps are used for detecting mosquito populations. An estimated 400-500 general purpose electric traps are in use to determine new infestations of economic insect pests. Special multipurpose traps are used at points of entry to detect foreign insects.

The first field scale test of light traps for insect control was initiated in a 113 square mile area in North Carolina in 1962. Here 366 traps of special design are used for catching tobacco hornworm moths. The results

of the 1962 and 1963 seasons have been promising and indicated that hornworm moth populations in tobacco can be reduced by use of electric insect traps when installed at a density of 3 per square mile over an area at least 12 miles in diameter.

However, in spite of the rapid and unprecedented progress in farm mechanization during recent years, many important field and farmstead operations are still not mechanized or are only inadequately mechanized. There are also many unsolved problems in the mechanical preparation and conditioning of farm products for farm storage and use, and for sale. There are many undeveloped opportunities for the more effective and extensive application of the different forms of electromagnetic energy and there is urgent need for the development of more effective and economic farm buildings for storing products, sheltering livestock, and farm family living.

In view of the rapid multiplication and widening distribution of nuclear weapons and the failure of all current efforts toward disarmament, plans for future agricultural engineering research may well give consideration to types of building construction that would afford protection from fallout for families, livestock and stored products in case of attack. Consideration might also be given to development of types of essential equipment, such as well pumps, that could be kept in operation in case of power failure.

Agricultural Engineering research is carried out by the Agricultural Engineering Research Division of the Agricultural Research Service of the U. S. Department of Agriculture, by nearly all of the State Experiment Stations, and by farm equipment manufacturers, manufacturers of building materials and prefabricated buildings, and to a limited extent by trade associations.

A characteristic of current Agricultural Engineering research is the relatively small program of the USDA and also of the State Experiment Stations in this field compared to that of public research in other fields of agriculture. This imbalance is serious because 80 percent or more of all agricultural research involves engineering, either during its conduct or during the application of its positive findings. Also as agriculture becomes more complex the need for expanded public agency research in agricultural engineering to determine for industry the fundamental principles and the basic requirements of the power, machinery and structures needed for an efficient agriculture become increasingly urgent.

Thus, although there is need for the expansion of independent basic research in agricultural engineering, there is also need for a considerable expansion of agricultural engineering research cooperative and concurrent with other related agricultural research programs and also cooperative with industry whenever circumstances indicate the desirability of such cooperation. It should be noted that public agency research in agricultural engineering is complementary to and often cooperative with private research and not a competitive duplication of research by industry.

The Agricultural Engineering Research Division has 30 of its 147 professional workers located at the Beltsville Agricultural Research Center; 10 at 8 Federal field stations, and 107 at 31 State Experiment Stations.

Of the 107 Department professional workers now at State Station locations, 31 are in 7 specialized Federal laboratories, such as the National Tillage Machinery Laboratory at Auburn, Ala. Most are working cooperatively with State-employed workers on mutually agreed problems that have both State and National significance. Much of the research is carried on by teams including both engineers and scientists trained in other disciplines.

The program at Beltsville includes leadership for work done in the field and research on problems of National interest. Basic research involving 28 engineers conducted at 16 locations, including Beltsville, deals with soil and equipment relationships, pesticides and fertilizers application, crop conditioning, cotton ginning, environmental requirements (including light) for livestock, electromagnetic radiation for seed and plant product treatment, insect attraction and destruction, and nondestructive determination of fat and lean on live animals. Most of the work at other locations is directed toward solution of specific problems.

The program of the Agricultural Engineering Research Division is reported under 14 Research Areas shown in the Table of Contents.

## AREA NO. 1: SOIL - MACHINE RELATIONSHIPS

Problem. The substitution of the internal combustion engine for animal power has been the major influence on the farmer's productivity during the first half of the twentieth century. There have been important developments in the tractor chassis and its accessories, such as tricycle chassis, power take-off, implement mounting, hydraulic controls, and pneumatic tires, but there is still a lack of fundamental knowledge and understanding of the method whereby tires and tracks transmit forces to the soil in developing traction. In view of the tremendous amount of power and energy which is used every year in farm field operations, all factors which may affect the efficiency of this use should be continually studied for potential improvements in efficiency.

There is need for basic information on how traction is developed by tires and tracks, and need for improved traction, and transport equipment. There is evidence that compaction of soils is becoming more common because of the increasing size of tractors and the more complete mechanization of field operations, particularly harvesting, which usually must be done at a given date regardless of the soil conditions; thus, associated with tire and track research is a need for study of methods of reducing soil compaction.

Tillage of the soil is the greatest consumer of power in the production of crops in the United States today. Some type of tillage operation is considered necessary prior to the growing of almost all crops. Despite this great need and cost, the tillage tools which are generally used have remained essentially unchanged since their invention, or most radical improvement, nearly 100 years ago, and very few innovations since have survived the tests of improved crops response and/or reduced cost of operation. While some tillage is needed for nearly all crops, there is good evidence that much unneeded and in some cases detrimental tillage operations are performed. The soil is a very complex physical system, containing inorganic and organic solids, liquids and gases, and its reactions to forces, manipulation, temperature, and water is unlike any other simple material. In view of the wide-spread use of, and great power consumption by, tillage, there is a need for expanded basic research to give more precise information on the inter-relationship of tillage, soil physical conditions, and plant growth; on the effect of soil mechanics upon the tillage operation; on the effect of equipment mechanics on the tillage operation; on mathematical methods which can be used to predict the effect of various forces on the soil; and on tillage methods and systems of equipment which are compatible with conservation farming practices. Intensive research is needed to determine the optimum tillage requirements, based on costs and crop response, for various soil, climatic and crop conditions.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers and soil scientists engaged in both basic studies and the application of known principles to solve problems dealing with the relationships between soil-engaging equipment and soil reactions. The research findings are applicable to tillage implements, tractive and transport equipment (such as tires, wheels, and crawler tractor tracks), and soil moving equipment (such as land forming and road building equipment). Work is cooperative with the State Agricultural Experiment Stations at Auburn, Alabama; Ames, Iowa; Athens, Georgia; State College, Mississippi; and East Lansing, Michigan. USDA personnel working on this project are stationed at Auburn, Alabama, and Ames, Iowa. Much of the work at the laboratory at Auburn is with manufacturers of implements and equipment for use in agriculture. The research is of a fundamental nature of value to the entire industry and directly and indirectly to farmers. It consists of theoretical analyses, basic laboratory studies, controlled soil bin tests and field observations.

The Federal scientific effort devoted to research in this area totals 8.6 professional man-years. Of this number 2.0 is devoted to traction and transport devices and soil reaction; 0.5 to the effect of tillage practices on plant growth; 2.0 to the measurement of soil physical properties; 1.5 to equipment mechanics; 0.5 to the effect of soil mechanics; 0.5 to methods of mathematical analysis; 1.0 to systems of equipment for conservation farming; and 0.6 for program leadership.

## PROGRAM OF STATE EXPERIMENT STATIONS

Many of the State agricultural experiment stations are engaged in both fundamental and applied research dealing with the development of new principles and the application of currently available knowledge to the problems concerned in soil-machine relationships in order to increase efficiency in crop production. These studies are concerned in the broadest sense with the development of theories, special devices, and laboratory and field tests to determine ways in which tractive and transport equipment, tillage tools and systems for their use might be improved.

Investigations are in progress on ways to develop and apply more efficient methods of soil manipulation that will produce improved soil physical conditions for seed emergence and optimum plant production; development and evaluation of systems of tillage which offer possibilities in reducing time, labor, or equipment to produce a crop; determination of fundamental and predictable relationships between external energy applications and soil breakdown and consolidation; exploration of techniques necessary for improvement of deteriorated soil structure and soil tilth; probing into possible ways that traction and flotation of farm machines might be improved to overcome the problems caused by compaction; and measurements of power requirements, stresses and wear on tools and equipment as an aid to improved farming efficiency.

Many of these research investigations are cooperative with the Department. A total of 19.9 professional man-years per year of research effort is devoted to this work.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Traction and Transport Devices and Soil Reaction.

1. This project is designed to determine and evaluate the effects of various constructions, materials, and operational factors on the performance of tires and tracks when used for traction and for transport.

The study to determine the effect of rim diameter on rear tractor tire performance has been continued. Tests have been made to measure more nearly the effectiveness of the tires when carrying rated loads rather than all tires carrying the same load. These tests were completed at the end of the year. Data have been worked up and results were reported in a paper at the annual meeting of ASAE, June, 1964.

A series of tests of five types of track shoes in five soils has been completed. Data have been analyzed and a paper "Effect of Track Shoe Design Upon Traction" was prepared for presentation at the June Annual Meeting of ASAE. The results show that grousers one inch high perform as well as higher grousers and that the snow and ice type is as effective as regular grousers for general work. Semi-grousers are less effective than regular grousers.

Tests comparing low pressure rear tractor tires with regular tires show definitely that they are effective traction devices and cause less soil compaction. The maximum drawbar pull developed for a given static load on the tire increased as the width of the tire was increased. It was not determined whether or not the compaction produced by the low pressure tires was still enough to hinder plant growth. A paper covering most of these tests was presented at the ASAE meeting in December, 1963.

A study made cooperatively with a tire manufacturer showed that three types of radial ply tires performed equally well. Their performance was significantly better than for a 4-ply tire having the conventional angle cord arrangement. The three radial ply tires were finished in the same mold and each had a 4-ply belt. The difference was in the number of body plies and the number of stages used in molding. Service and cost studies will be necessary to determine whether or not one or more of these experimental tires should be considered for production.

The study designed to determine the possibility of developing a torque rating comparable to the static load rating for rear tractor tires was continued in cooperation with the SAE Tire and Rim Agricultural Subcommittee Task Groups. Data were obtained for 5 tires on two soils and concrete. Tires were operated at static loads recommended in the T & R Yearbook and

at loads 1.28 times this amount. Torques at which slight, medium, and severe buckle occurred were recorded. These data are being studied. Additional tests and study are needed before recommendations can be made.

A cooperative research project has been undertaken with the Bell Telephone Laboratories to study the tractive capabilities of traction devices on submerged soils. This requires that the devices will be operated on soils having at least 6 inches of water on the surface, a condition frequently found in rice fields. A new traction measuring unit is being developed and built to enable operating a number of sizes of tracks in soft soils. Some soil bins at NTML are being modified to permit submergence. The complete test program will be developed on the basis of results obtained during the initial part of the test program. The results should provide a basis for the design of a practical traction system that will give optimum performance in submerged soils. The initial phases of the planned traction program should be completed during 1964.

A test covering 10.00-20 single, 10.00-20 dual, 14.00-20 single, and 16.5-21 single tires on concrete and in sand was made to determine the effectiveness of these tire sizes and combinations for use on highways and for off-the-road operation at highway inflations. It was found that the 16.5-21 had slightly greatest traction loss on wet pavement and was slightly less adaptable to loose sand at highway inflations. It was acceptable at lower inflations. The 14.00-20 gave slightly better tractive performance. The effect of dualing varied with moisture content in sand.

One radial ply tire with lugs cut to produce three degrees of stiffness was tested in two soils and on concrete. Slitting the lugs made no difference in performance in the soils. However, on concrete, one slit per lug reduced the pull 4 percent at 38 percent slip, and slits spaced 2-1/16 in. apart caused a drop of 10 percent. The slit tires lost noticeably more rubber at 38 percent slip.

#### B. Effect of Tillage Practices on Plant Growth.

1. Deep Tillage for Cotton. The maintenance of loose soil in trenches which are not subjected to compaction should result in deeper root penetration and better moisture extraction. Plots of this type were established and used in these experiments. Unfortunately the entire area of this experiment was inadvertently deep tilled. The experiment was continued but yields were low and very erratic. It was concluded that the experiment should be terminated since the desired differences in soil conditions were destroyed by the tillage. Future work will be undertaken at a new location on the Ingram Farm at Marvyn, Alabama. The new experiment will attempt to determine whether cotton roots are restricted by mechanical resistance, low pH, or lack of oxygen, in a Norfolk sandy loam soil.

2. Minimum Tillage for Potatoes. Conventional pre-plant tillage takes time, costs money and may serve no value. The study of primary pre-plant

tillage involving deep tillage in the Spring, deep tillage in the Fall, Fall plowing, Spring plowing, and no tillage whatsoever (planting directly in wheat stubble) was repeated for the third year. Potato yields and clod measurements were in harmony with the previous two years' results. The yield and amount of clods were not effected by pre-plant tillage practices. In fact, in all three years, potatoes planted directly in wheat stubble resulted in greater yields and slightly fewer clods. The results of this phase of the research is being prepared for publication and should be available in the summer of 1964.

#### C. Measurement of Soil Physical Properties.

1. The work of this project attempts to establish means of describing the relations between soil physical conditions and tillage tools and the response of soil to the tools. Such quantitative relationships will be useful in the design and operation of tillage machinery. It includes basic laboratory studies, bin tests and field tests.

Equations of similitude were developed for triangular chisels operated in a vertical position. Tests were conducted on one loam and one clay soil. The tests verified that the similitude equations permit predicting from the draft of the smallest model the draft of any prototype for each soil.

This year completes the fifth year of a 5-7 year planned program on peanut production cooperative with Georgia. Peanut yields were influenced more by the previous crop than by the tillage operations. These results are consistent with those reported in 1961.

The study on abrasive wear was continued to evaluate various plastic and steel materials and to determine relative abrasiveness of soils. Polyethylene compared favorably with Teflon in a laboratory study using a commercially available wear tester. It wore more rapidly than Teflon in field trials. Tests using 11 different soils show that wear on steel is proportional to percent of sand and silt in the soil. Wear of Teflon was fairly uniform until a value of 80 percent sand and coarse silt was reached.

The continuation of plowing operations at a deeper depth has resulted in the decreased production of large clods from year to year. Influence of deep plowing as reflected by decreases in soil resistance remained through the winter but this influence has not been reflected in depth of rooting. The Teflon covered plow scoured well in all soil conditions encountered.

#### D. Equipment Mechanics.

1. Basic studies of disk design and operating parameters have been continued with full scale and model tools. A comparative study of soil-tool force reactions on regular disks and a "Vertedor" disk produced in Argentina was made in 3 soil conditions using a constant depth and width

of cut with varying disk angle. It appears that the "Vertedor" disk does a much better job of inverting the furrow slice, and in lighter soils does not require the application of as much power to pull the disk through the soil as the regular disk.

In studies of full scale and model disks, the forces acting on disks during test runs of increasing and decreasing speeds were compared to those measured during constant speed runs in the same soils. It was found that the additional force caused by acceleration can be of significant magnitude if the change in speed is made rapidly.

#### E. Methods of Mathematical Analysis.

1. This project attempts to develop mathematical expressions to describe and predict the behavior of soil when forces are applied to it and when machines come in contact with it. This year a number of experiments were performed at Auburn, Alabama with a new elementary soil-machine system to see if its behavior could be described and predicted mathematically. A ring-shaped plate with short rigid lugs on it was placed on the soil, a vertical load placed on it, and it was then rotated about a vertical axis. The vertical load, the sinkage, the slip, and the torque required to rotate it were measured on various soils. Similar experiments were done with another ring-shaped plate with a smooth, rubber covered surface rather than lugs.

It was found the results of the tests all could be described by the equation

$$S = C - p^{1-n} J^n T$$

where S was the tangential force (torque divided by average ring radius), P was the vertical load on the ring, and J was the slip. The quantities C, T and n depended on the traction surfaces, and soil type and condition. The new equation not only fitted data from these experiments, but also the data from similar experiments conducted by the Army.

#### F. Systems of Equipment for Conservation Farming.

1. In many locations in Iowa early spring application of herbicides to control weeds made it possible to grow corn successfully, following corn, without tillage. On fall or spring plowed land, near Ames, all secondary tillage and cultivations were eliminated through the use of early spring applications of herbicides without affecting stands or yields. On unplowed corn ground, the herbicides were used to eliminate all tillage operations but resulted in erratic stands. If weeds can be controlled chemically and if satisfactory stands are obtained, soil disturbance with tillage tools may be unnecessary. On soils conducive to crusting, some soil disturbance during the season is beneficial for soil and water conservation by increasing water infiltration and reducing erosion hazard.

The self-recording automatic "soil profilemeter" was refined and used to measure surface roughness and porosity changes in the tilled soil layer.

Plowing with a moldboard plow caused approximately a 25 percent increase in porosity. A mathematical procedure was developed using point profile readings to develop a roughness coefficient. Tillage operations had little effect on subsequent soil temperature and moisture. Bulk density measurements show a considerable increase in density with tillage operations following plowing.

G. Foreign Research Under Public Law 480 Funds.

1. The second year of a 4-year research project contract under PL 480 funds with the Agricultural Research Station, Beit Dagan, Israel, has been conducted. This research concerns tillage methods and implements for mountain farms. Field experiments were carried out with a moldboard plow and a disk plow in order to obtain detailed information on the actual movement of soil from furrow to furrow when plowing a hillside along the contour. Uphill casting with the disk plow, and uphill and downhill casting with the moldboard plow were compared on 7 to 10 percent hillside slopes in a heavy soil with 10 to 14 percent moisture content.

According to results, translocation of soil with the moldboard plow is largest when casting downhill, but still considerable when casting uphill, on slopes of 7 to 10 percent. The uphill movement of soil with the disk plow is slightly less. No significant difference was found between the two slopes. Much more soil (34 to 39 percent) fell back when casting was done uphill with the moldboard plow than by casting downhill (10 to 20 percent). The returning soil ratio of the disk plow casting uphill was smaller (24 to 25 percent), probably due to its large width to depth ratio. The returning soil not only decreases the lateral movement of soil, but also interferes with the free passage of the tractor wheel in the furrow for a tractor-mounted plow or the furrow wheel of a trailed plow, and makes uphill casting on steep hillsides a very difficult task. Improvements of the observation method are planned during further investigations in this project.

2. A 3-year grant was awarded to the University of Bologna, Italy, in October, 1963 under PL 480 funds to study equipment and methods for breaking up cohesive soils into small clod sizes at depths of as much as 3 ft. Land has been obtained, instrumentation and equipment is being prepared, and the research is getting underway.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Systems of Equipment for Conservation Farming.

Schafer, R. L., Bockhop, C. W., and Lovely, W. G. 1963. Vane and Torsion Techniques for Measuring Soil Shear. Trans. of the ASAE, Vol. 6, No. 1, pp. 57-60.

## AREA NO. 2: PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT

Problem. The history of the development of planting equipment now in use is characterized primarily by invention of machines which will plant seed in accordance with accepted practices. Introduction of chemical fertilizers was followed by specialized equipment for spreading this material. Early work on placing fertilizer close to the seed (starter fertilizer) was followed by the discovery that a certain position with respect to the seed resulted in the best response to starter fertilizer for particular crops.

However, there has been very little work on, and there is considerable present need for, precise seedbed requirements for various crops in different areas of the country. This seedbed requirement would include depth of cover, size of soil particles or clod surrounding the seed, degree of soil compaction necessary, and soil surface profile over the seed for best emergence. The row spacing used on many crops is still that which was necessary to permit horse cultivation. The exact best planting geometry for many crops is still unknown. The exact best placement for starter fertilizer is also unknown for a number of crops in different areas of the country. There is also a need for development and testing of fertilizer application equipment for unusual crop situations, such as hillside orchards, sugarcane, tree transplants, etc. While efforts in precision planting of crops in the past have not often resulted in discernible yield improvements, there is a renewed interest in precision planting of vegetables to improve uniformity of maturation to facilitate mechanical harvesting. As other needs for hand labor diminish and it becomes less available on farms, there will be an increasing need for completely automatic transplanting equipment which does not yet exist. There is an acute need for new and improved equipment and methods for effective planting of native range grasses in the arid areas of the Southwest which will result in a greater certainty of stand. Equipment is needed which can be used to re-seed relatively rough areas which are overgrown with undesirable species or have recently been cleared. There is also need for improved planting equipment and methods for forage crops in humid areas. Approximately a third of such plantings now result in poor stands and another third result in no stands at all.

Two large items of expense in cotton production are seedbed preparation and planting. Preliminary work has indicated that more than optimum primary tillage is being done in many cotton areas resulting in wasted horsepower, unnecessary soil compaction, moisture losses and increased cost. In planting, more precision and timeliness is needed to assure the rapid emergence of uniform stands. This will require more basic knowledge of the micro-environmental requirements of the cotton seed, and more automatic sensing and control mechanisms in planting equipment. More precision in the control of the seedbed shape, size, and position will also have a direct bearing on the economical use of new and more potent pesticides.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of applied engineering research on planting methods and means of applying fertilizer on various crops. Studies are in progress at 22 locations in 11 states (Arizona, Florida, Georgia, Indiana, Louisiana, Maryland, Michigan, Nevada, Oklahoma, Texas, and Washington). Forty-four field experiments were conducted in cooperation with state experiment stations, other ARS divisions, and commercial research units, which involved studies with 23 crops. Nineteen special machines were provided to put in seed and fertilizer placement experiments this season. These machines were designed and constructed by the Investigation Unit. Three new machines or modifications of previously designed special machines were designed and constructed by staff research engineers.

The Federal scientific effort devoted to research in this area totals 9.6 professional man-years. Of this number 1.0 is devoted to fertilizer placement and distribution equipment; 0.2 to seed planting equipment; 0.4 to transplanting equipment; 2.0 to equipment for establishment of forages; 2.9 to cotton seedbed preparation, planting, and fertilizing equipment; 0.4 to vegetable planting equipment; 2.0 to decontamination of agricultural land; and 0.7 to program leadership.

## PROGRAM OF STATE EXPERIMENT STATIONS

Problems concerned with planting of the many sizes and shapes of seed of agricultural crops together with the introduction of fertilizers for use by these crops are under attack by many of the State Agricultural Experiment Stations. A considerable amount of this work is cooperative with the Department. These studies are concerned with the development of new principles that can be used to meter and place seed which could lead to planter improvement. Similar investigations are in progress to develop satisfactory metering and placement devices for application of liquid as well as solid fertilizers. In both instances the principal objective is to provide the best possible means of seed and fertilizer placement which will assure healthy plant emergence with vigorous growth to maturity.

Involved in these studies are design and testing of the several elements of machines together with investigations of the mechanics of seedling emergence. Basic research is also underway in an effort to determine the environmental conditions that are necessary for maximum emergence and how these conditions may be controlled or altered with mechanical equipment. Companion to these overall studies are limited testing, improvement and development of equipment for aerial applications of seed and fertilizer.

A total of 11.7 man-years per year of research effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Fertilizer Placement and Distribution Equipment.

1. Nineteen experiments on the establishment of field crops and vegetables were put in cooperatively with various State, Federal and commercial research units. Some typical results or trends shown of the field experiments of field crops are: Fertilizer placement experiments on small grains at two widely spaced areas (North Indiana and Central Georgia) showed great similarity in reduction of early germination when fertilizer was placed in contact with seed -- 50 percent or more reduction on 3 soils in Indiana with winter wheat (30 lbs. per acre N, 120 lbs. P and 120 lbs. K per acre - stand counted 30 days after planting). In Georgia, the plant counts the first 5 weeks showed fertilizer contact reduced stands to only 1/4 those with 1" x 1" side placement of fertilizer. This was true on both winter oats as well as winter wheat. Applying these initial findings to field practice, the cost of production of these widespread winter grains can be reduced because less seed is required to produce a satisfactory crop.

B. Equipment for Establishment of Forages.

1. Thirteen experiments on the establishment and production of pastures and haylands were put in cooperatively with State and Federal research units. Typical results that show response or definite trends from new planting or application methods in the various studies are: In a study of stabilizing sand dunes in the southern great plains, exploratory trials indicated the direct use of fertilizer on the dunes enabled the native grass seeds to grow and showed greater response in checking the devastating advance of dunes on productive lands, than the attempted methods of establishing vegetative mulch cover or the establishment of new grass species on the dunes. This is a cooperative study with the S&WCRD and Oklahoma & Texas Experiment Stations. In the inter-seeding of desired species in abandoned rangeland in the Southwest, side-oats grama was placed with and without fertilizers and legumes in March, April and May. About three times as many plants emerged and survived from the May plantings in comparison with March and April. Although the emergence and survival of side-oats grama were better on plots without fertilizer or legumes, the forage production at the end of the season of the plots with the combination treatments was approximately 50 percent greater than the grass plots alone.

C. Cotton Seedbed Preparation, Planting, and Fertilizing Equipment.

1. Complete crop residue disposal by destruction of the roots as well as the stalks has been found desirable in previous research, but adequate and economic equipment for this operation has not been available. This year in Mississippi promising results were obtained in preliminary field tests of a commercial machine which shreds the plant with twin horizontally rotating blades and uproots and masticates the stubble and root crown with

an integral rotary tiller. Preliminary design and development was begun on another machine to dispose of the entire plant without shredding by depositing it in a vertical subsoil trench.

2. Precision tillage (deep subsoiling under the row) increased cotton yields and plant response again in California, particularly in lighter soils. The two most important factors for success of precision tillage were found to be proximity to the drill row and sufficient depth to penetrate through the compacted layer.

Precision tillage gave slightly higher yields than other tillage methods and slightly better than last year at 2 locations on fine sandy loam soils at Lubbock and Stoneville. Although disk harrowing following other primary tillage treatments resulted in a finer seedbed and better stands, yields were lowest in these and the middlebreaker plots.

3. A minimum tillage system, used for the second year in California required less than 30 percent of the horsepower hours of the normal system. The draft requirements for precision tillage (20" to 24" deep) were found to be 2120 pounds per shank in Hesperia fine sandy loam and 4070 in Panoche clay loam soil.

4. In a study of transferring soil layers, Tunica silty clay, a stratified clay over sand deposit, was mixed thoroughly to a depth of 30 inches with specialized equipment in Mississippi. Mixing improved infiltration rates, internal drainage, and reduced the power required for plowing 35 percent. Although moisture was not sufficient to settle the excavated and inverted layers of soil in time for proper smoothing, yields were improved significantly over the standard practice of shallow bedding; but subsoiling to comparable depths gave the same results. The long-term effects of the soil mixing will need to be evaluated.

5. Liquid fertilizer equipment was adapted to a tractor-mounted 4-row lister at Lubbock for applying fertilizer simultaneously with bedding.

6. Precision depth planting was accomplished at Lubbock by a newly designed planting attachment that regulated the seed furrow opening shoe depth by a threaded rod adjustment and was controlled at a constant height with a gage wheel operating on the bed by the side of each opener. Several commercial and one experimental press wheels were tested for the pressures they transmit to the covering soil during planting. All of the press wheels except the experimental wheel produced pressures above 2 psi which has been found to hinder emergence under certain conditions in previous research results.

Similarly, under the planting conditions at Shafter, the use of any soil surface compacting tool following planting was detrimental to stands. Crust strength varied from 37 psi for no compacting wheel to 307 psi following a rubber press wheel. Hill-dropped cotton emerged through hard

crusts better than drilled cotton. The loss of cotton seedlings to disease was found to increase with higher rates of seeding and with closely spaced hills.

7. At Lubbock cotton came up two days earlier from pre-emergence asphalt mulch plots, and a slight increase in yield was obtained where mulch was sprayed as a pre-emergence application or when applied pre-emergence plus post-emergence. Yields were reduced by mulch where it was applied as a post-emergence treatment only. Although moisture retention was better, there was no significant increase in temperature when rates were increased from 50 to 300 gallons per acre.

One of the greatest drawbacks to experimental synthetic mulches and other chemicals is often the cost of material. The amount of petroleum mulch required was reduced to 20 percent at Stoneville by the precision placement of spots over hills of hilldrop cotton. The hilldrop mechanism of the planter was timed with an air solenoid valve in the spraying system. Results from the small spots of application were equal to those from the continuous band application.

#### D. Vegetable Planting and Fertilizing Equipment (including potatoes).

1. On irrigated potatoes in Nevada, four fertilizer ratios plus a systemic insecticide (Thimet) for the control of sucking insects, were compared to similar plantings without the use of the insecticide. All ratios contained 180 lbs. of  $P_2O_5$  per acre, but the N was varied from 300, 200, 100, and 0 lbs. per acre. With the insecticide, the 100 lb. rate of N produced a yield equal to that from the 200 lb. rate of N without the insecticide. The  $P_2O_5$  and the first 100 lbs. of N were placed 4 in. on each side and 2 in. below the seed piece, and the additional N was top dressed when the plants were 5 in. high. By using the combined fertilizer-insecticide, the cost of production of potatoes per acre can be materially reduced - by the saving of 100 lbs. of fertilizer per acre and one trip over the field.

#### E. Decontamination of Agricultural Land.

1. Our previous research has given us knowledge of how effective various types of farm and earth moving equipment are in removing fallout. This year the first study was made to determine how much time is required to remove and bury the contaminated surface soil using a road grader, the most efficient means we have found. About nine hours were required to decontaminate 100,000 square feet (about 2.3 acres) and bury the soil in ditches in the field. The ditches were excavated by the large grader. Corn fields with large root systems and irregular ground surface are quite difficult to decontaminate in this way. Other methods of decontamination were investigated on a field of corn which was contaminated and harvested. Different parts of the field were harvested with a flail harvester, corn picker, and combine. About 13 percent of the activity was removed in the

chopped corn; 0.25 percent in the picked corn; and 0.35 percent in the shelled corn. The road grader was less effective over corn stubble than over other surfaces. It removed only 47 percent of the activity from the chopped plots, 57 percent from the picked plots, and 63 percent from the plots which had been combined. Tests in which a cement slurry was applied to the ground and then removed with the fallout clinging to it were unsuccessful because of the difficulty of producing and spreading an even slurry.

Attempts were made to plow under contaminated surface soil to a depth where it would be unavailable to roots. This was done with a Post Brothers Model PB142 large plow which made furrows 30 in. deep and 42 in. between furrows. The plow is about 6 ft. high, 9 ft. wide and weighs 6,000 lbs.; it was pulled by two D-8 tractors (the largest tractor used by the Army Corps of Engineers). Soil profiles through fluorescent and radioactive tracers indicated that some of the surface soil was buried no deeper than 1 ft. with the large plow. However, much deeper burial should be possible with this equipment. More burial work will be done with this large plow, and with a ditch digger.

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AREA NO. 3: CROP PEST CONTROL TECHNIQUES AND EQUIPMENT \*

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the method which is attempted or recommended.

Thus, equipment to control a wide variety of pests on a wide variety of crops is required. This requirement is partially met by the sprayers, cultivators, dusters, and soil injection equipment now available. However, mechanical cultivation does not always produce satisfactory weed control, and it is time consuming and costly. It is believed that with sprayers and dusters now used, often no more than 10 to 20 percent of the chemical goes onto the plant. Methods of applying nematocides in the soil do not always result in uniform nematode control, and untreated soil below the treated zone, in untreated pockets, and at the soil surface, provide sources for quick reinfestation.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Chemical insect and disease control research is conducted at the Grain Insects Research Laboratory at Tifton, Georgia, chiefly on corn insects; at Ames, Iowa, particularly for corn borer control; and at Wooster, Ohio, on improved equipment for corn borer control. Disease control research is also conducted at Wooster, Ohio. Weed control research, chemical and cultural, is conducted at Ames, Iowa; St. Paul, Minnesota; Columbia, Missouri; and Stillwater, Oklahoma; and at Wooster, Ohio, where a small part of an engineer's time on spraying equipment applies specifically to

\*Except electric, which is in Area 11.

weed control. Aircraft application equipment is studied at Beltsville, Maryland, in cooperation with the Forest Service; and at Forest Grove, Oregon, in cooperation with the Oregon and Washington Stations, on low growing crops. Pest control equipment research for certain crops is conducted; for cotton at Auburn, Alabama; Stoneville, Mississippi; Shafter, California; Lubbock, Texas; and (particularly for boll weevil control) at State College, Mississippi; for vegetable crops at Forest Grove, Oregon, and for brush control at Mayaguez, Puerto Rico and College Station, Texas.

The Federal scientific effort devoted to research in this area totals 14.4 professional man-years per year. Of this number 1.7 is devoted to basic studies in aerosols and spray formations; 1.0 to soil fumigation; 2.8 to insect control in grain; 1.3 to weed control in corn and soybeans; 2.7 to pest control in cotton; 1.0 to insect and disease control by ground equipment in vegetables and other low-growing crops; 0.9 to aircraft equipment for application of pesticides to vegetables and other low-growing crops; 1.0 to aerial spray equipment for forest insect control; 0.8 to brush control equipment and methods; and 1.2 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Both basic and applied research investigations which have been designed to discover and develop methods, techniques, and equipment for control of the many pests that attack our economic crops are in progress at the several Agricultural Experiment Stations. Much of this work is cooperative with the Department.

These studies are involved in the complicated objectives of furthering the efficiency and the means for better control of insects, plant diseases, nematodes and weed problems through application of engineering knowledge on the use of aerial and ground chemical applicators for liquids and dusts, flame cultivators and mechanical devices for soil manipulation and soil fumigation.

A total of 2.7 man-years is devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Studies in Aerosols and Spray Formation.

1. Mathematical and experimental studies on the basic transport, spreading, and distribution processes for fine particles suspended in turbulent gases were continued at the Pioneering Research Laboratory on Physics of Fine Particles at Wooster, Ohio. An instrumentation system is under development for measuring the distribution of fluorescent-traced particles on deposition surfaces to facilitate the study of relations between deposit distribution and the turbulence producing it. A method of spectral analysis has been developed which appears to be applicable to the measurement of surface deposit, but which needs further study. The use of a tape

recorder has made experimental procedure immeasurably easier than if one attempted to process the "live" signal directly. Additional work is being carried forward in the areas of heat and moisture diffusion in fine-particle starch doughs, and in electrical diffusion of clay suspensions.

## B. Soil Fumigation.

1. Field treatments were made in cooperation with the Ohio Station in order to study and develop methods and equipment for applying chemicals to soil for the control of crop pests. A number of volatile materials are now available in pressurized cylinders or bottles similar to the containers used for oxygen, nitrogen and other compressed gases. By using an appropriate regulator, these materials are easily applied by the field cultivator equipment with injector blades. Applications of this type made for control of Verticillium in vegetable plantings gave substantial increases in yield but the materials do not give the desired control of this disease. Measurements made of cherry trees planted in soil treated with several different nematocides in 1957 and 1960 show increased twig growth and greater spread of branches than in untreated plantings.

Applications of herbicides by a rotary tiller type of applicator, operated with forward travel per blade cut ranging from 1.5 to 4.7 in., show best result with the short cut. The short cut is believed to give a better resultant mixing of non-volatile chemicals with the soil.

Latex, asphalt and wax emulsions were applied to soil as surface mulches. This had previously been found to increase plant growth including weeds. Several formulations including different herbicides were applied. Generally these formulations appeared to produce some seedling injury and reduction in stand in vegetables on which they were used.

## C. Insect Control in Grain.

1. In investigations for the control of the European corn borer, made in cooperation with the Iowa Station, the major emphasis of the chemical control program was the screening of new insecticides, development of systemic insecticide control, study of effect of particle size and amount of carrier in the granular formulations, study of the rate of loss of insecticide residue on corn plants, and study of effect of chemosterilants on corn borers. The results of these studies indicate that in addition to the presently recommended insecticides, the following also gave good control of first- and second-brood corn borer larvae: Telodrin at 0.2 lb. per acre, diazinon at 2 lb. per acre, Bayer 25141 at 2.0 lb. per acre, and Velsicol bromochlordene at 1.5 lb. per acre. The following showed systemic activity against corn borer larvae: American Cyanamid 47470, 47826, and 47938; Niagara 9203, and Bayer 39007. Granule size and amount of dilution of granular insecticides influence the degree of control of both first and second brood larvae. Residues of diazinon found on corn treated for corn borer control did not exceed established tolerances on corn kernels or corn forage.

2. New methods of controlling grain insects are being attempted at the Southern Grain Insects Research Laboratory, Tifton, Ga. It was thought that the orientation of corn ears and foliage in the row would be of assistance in the application of insecticides, so some corn seed were oriented at the time of planting to determine if the direction of ear and foliage growth could be predicted. Seed planted with their germ side across the row, produced 53.8 percent of the ears pointing in the direction of the row. Seed planted with their germ side paralleling the row resulted in 61.4 percent of the ears across the row. There was no orientation of the foliage on either of the rows.

Because of the rapid growth of corn silks, it was thought that a gelatinous substance might be useful for protecting new silks from insect attack. Carbowax solutions (with DDT) were applied to corn ear tips and silks for insect protection. Better protection resulted from the carbowax treatments, but the treated ears tended to rot. Other gelatinous materials that might have merit will be tested as they become available.

An electrostatic duster was evaluated by measuring insecticide deposited on sweet corn under field conditions. The insecticide dust was applied through nozzles either uncharged, positively charged with 13,200 volts, or negatively charged. Samples were taken for residue analysis during a period of 174 hours. The initial concentration of dust on the plants was 57 and 36 percent greater with positively and negatively charged particles, respectively, than with uncharged particles. The rate of residue decline with time was essentially the same for all treatments.

3. An insecticide (DDT) in the form of spray, dust, and granules was applied to sweet corn in Georgia at the one- and five-day silk stage by means of conventional equipment and techniques. Applications were made at 2 lbs. per acre, the rate recommended for controlling the corn earworm. Samples were taken during an 8 day period, and the insecticide residues were determined by gas chromatography. Higher residues were obtained with granules than with dust, while residues from spray were lowest. Variations in the quantities of DDT deposited by dust and granular treatments were about twice that of spray.

4. Further studies were made in Georgia in search of a method for evaluating distribution of insecticides on corn ears and silks. Of the dyes compared for use as indicators of spray coverage, Rose Bengal and methylene blue were considered the best. However, the use of dyes was not altogether satisfactory as a long process was required for measuring the coverage by the methods used. Search will be made for a better method of determining residue distribution.

D. Weed Control in Corn and Soybeans.

1. In investigations cooperative with the Iowa Station, overall spray applications of Atrazine and Simazine on fall plowed, spring plowed, and unplowed ground controlled weeds in corn throughout the season. When 2,4-D was used, 2 cultivations were required for adequate control. Residues accumulated after 4 years of continuous corn reduced the effectiveness of all herbicides. With the exceptions of Atrazine and Simazine, granular herbicide formulations controlled weeds as well as or better than liquids when used at planting time. One additional cultivation was required with band applications as compared to overall applications of pre-emergence herbicides. Soil incorporation with row-wheels, rotary hoes, drag harrows, and dragging hoes did not improve the effectiveness of liquid or granular formulations of pre-emergence herbicides.

Essentially weed-free conditions throughout the year were obtained on 7, 14, 20, and 21-in. corn rows in Iowa with an overall application of Atrazine spray at planting time. However, some weed recovery did take place on 28- and 40-in. rows. With a rotary hoe operating at a 2-in. depth, excellent weed control was obtained on continuous corn on ridges. Ground corn as a carrier for 2,4-D in granular formulations demonstrated the same effect as clay when used in Iowa at various rates at planting time. Atrazine granular sizes of 20/25, 25/30, and 40/50 showed no difference in effectiveness when applied at planting time.

Seven-in. band applications of pre-emergence herbicides were as effective in Iowa as 14-in. bands for weed control in soybeans. The dragging rotary hoe was quite effective for weed control in beans as compared to the conventional rotary hoe but caused greater stand reduction. Using disk hillers for cultivating soybeans improved weed control as compared to the use of conventional sweeps.

Final field studies were made in Missouri to determine the effect of row spacing on Clark soybeans with and without pre-emergence treatments of Amiben at a rate of 3 lbs. per acre. Mechanical cultivations with the rotary hoe and sweep cultivator were also included in this study. Rotary hoeing in the 8- and 16-in. row spaces did not appreciably reduce the weed yields or increase the soybean yields when used alone, but when Amiben was used, rotary hoeing did not appreciably affect weed yields but significantly increased soybean yields. Amiben controlled weeds more effectively in narrow-spaced soybeans than in the wide-spaced soybeans. Sweep cultivations of 24, 32, and 40-in. rows decreased weed yields and increased soybean yields.

Field studies were initiated this year in Missouri to determine the effectiveness of 8, 10, 12, 14 and 16-in. band applications of 2,4-D (2 lbs. per acre), Simazine (2 lbs. per acre) and Atrazine (2 lbs. per acre) for weed control in corn. Narrow band applications of all herbicides were just as effective as wide bands for weed control. Eight and 10-in. bands

were more difficult to cultivate than the wider bands. Band applications of Simazine and Atrazine treatments resulted in higher corn yields than 2,4-D. Considerable reduction in application cost could result by using narrow bands.

Field studies were initiated this year in Missouri to determine the effectiveness of 8, 10, 12, 14 and 16-in. band applications of Amiben and NaPCP for weed control in soybeans. More weeds, but increased soybeans yields, were found in plots where Amiben was applied in narrow bands. Weed control and soybean yields were just as good in plots receiving narrow band applications of NaPCP as they were in plots receiving wide band applications. Weeds were controlled over a band wider than the applied band after rainfall occurred.

2. Initial field studies were made to compare the effectiveness of four methods of incorporating three pre-emergence herbicides for weed control in corn. Trifluralin, Atrazine, and 2,4-D butyl ester were applied at 2 lbs. per acre and EPTC was applied at 3 lbs. per acre. All herbicides were applied after planting and incorporated with a drag harrow, tandem disk, rotary hoe, Gandy Ro-Wheel with spray nozzle in front, and Gandy Ro-Wheel with spray nozzle in back. Incorporating with the disk resulted in better weed control but more corn damage. The rotary hoe and drag harrow resulted in fair weed control and least damage to the corn. The Gandy Ro-Wheel was as effective when the herbicides were applied ahead of the wheel as they were when applied behind the wheel, and overall it was about as effective as the disk harrow or rotary hoe. All incorporation resulted in increased weed control with the herbicides used.

Final field studies were made to determine the effect of rainfall (by irrigation) or soil moisture on weed control with granular and liquid formulations of 2,4-D ester. The addition of moisture increased weed control with granular formulations more than it did with liquid formulations of 2,4-D. Some corn damage and stand reduction were noted when water was applied to treatments of liquid formulations of 2 lbs. per acre of 2,4-D. The results of four years research indicate that there is a possibility of reducing the amount of herbicide used if moisture is made available to the herbicide after application.

Field studies were initiated to compare the effectiveness of 10 and 6.6 percent concentrations of granular Amiben (3 lbs. per acre) for weed control in soybeans. Increasing the total amount of granules while applying the same acid equivalent did not result in increased weed control or soybean yields. The liquid formulation of Amiben was just as effective as the granular formulation. Studies will be continued with additional investigations of herbicidal movement in soil.

✓ Laboratory studies were conducted to determine the effects of herbicide concentrations and mixing temperature on the relative viscosity of oil-in-water and water-in-oil (invert) emulsions of 2,4,5-T. The relative

viscosity of water-in-oil emulsions (water as base) measured with the Stormer viscosimeter was affected more by mixing temperature than it was by concentration of water when mixed within ranges suggested by the manufacturer. The effect of the same variations were not so easily described when using oil-in-water emulsions.

Laboratory studies were conducted to determine some of the metering characteristics of several granular herbicide carriers. The effect of carrier type, granule size distribution, granule moisture content, flow rate and agitator speed were determined when granules were metered with the Gandy and Noble applicators. Increased variation in rate of change in flow rate per change in agitator speed resulted with large flow rates for the Gandy applicator. This change in flow rate variation was larger and more erratic for the Noble applicator than it was for the Gandy applicator. Additional moisture did not change the flow rate characteristics when measured on a weight basis.

#### E. Pest Control Equipment for Cotton.

1. Chemical weed control has made it feasible to grow cotton broadcast or in very narrow rows in the high plains area of Texas. At Lubbock, a pre-emergence chemical, Diuron, was sprayed broadcast over a plot of cotton planted in 9 in. rows at the rate of 1 lb. per acre, and the block was sprinkle irrigated to activate the chemical. Excellent control of broadleaf weeds was obtained and the cotton was grown without cultivation or hand hoeing. Hand hoeing was significantly reduced in 40 in. row cotton by the use of a post-emergence spray of Diuron plus a surfactant.

Laboratory and field evaluation of granular herbicides in Alabama showed that slight changes in nozzle height did not materially affect granule distribution. Across-the-row distribution was non-uniform and varied between two nozzles of the same design. Liquid-treated plots required slightly less hoe time than granule-treated plots. The machine loading time for handling granules was 0.5 min. per acre compared to 3.3 min. for handling liquids.

Studies of nozzle wear with 4 different nozzle materials were concluded in Mississippi and Alabama this year. Results showed that stainless steel or hardened stainless steel orifices are much more resistant to wear and are more economical than brass, particularly when wettable powder formulations are used. Brass tips should be recalibrated frequently to maintain the correct application rate. The highest rate of flow increase occurred during the first 3 hours of spraying. No relationship existed between nozzle wear and spray pattern characteristics as long as the pressure was maintained.

In flame weed control studies, further modifications were made in methods of mounting and operating the experimental middle burners reported last year. Preliminary tests were also conducted to see if this device might

be used to destroy boll weevils in fallen squares. In cooperation with the USDA Boll Weevil Laboratory, temperature measurements were made within the squares at different tractor speeds. Results indicate that with speeds less than 1 mile per hour the middle burners would give a satisfactory kill, but further study is needed.

Fungicides for boll rot control were studied in cooperation with the Pathology Department at Stoneville. A quantitative measurement of chemicals deposited on bolls was developed. The system consists of correlating volumetric displacement of the boll to boll surface size. Laboratory equipment was developed to wash a fluorescent dye deposit from the boll and at the same time read the liquid displacement of the boll. Dye concentration can then be determined in a fluorometer and can be recorded as pounds of material per square unit of boll surface area.

A two-row cotton picker chassis was stripped of picking equipment and adapted to the application of pesticides in cooperation with industry engineers in Mississippi. Equipment included a 240 gal. tank, 12 row boom, and post-emergence directional spraying rigs. The machine provided adequate power and vertical clearance, good visibility for the operator, easy control of boom height and adequate lifting capacity as well as better utilization of equipment.

2. Refinements were made in the combination underground chemical applicator and planter to give more uniform application under a wider variety of planting conditions. The tri-band method of application of EPTC gave good control of nutsedge and annual weeds. Seedling Johnsongrass was also controlled in one test by applying Diuron in a tri-band. The work will be concluded on this specific equipment after one more year's research in Mississippi if the results are consistent with those of the past two years. Several methods of post-emergence sub-surface application of herbicides were investigated for weed control in skip row cotton. Two methods were deemed worthy of further investigation: (1) the Stoneville sub-surface applicator attached across the beams of a conventional cultivator, and (2) a small disk coulter followed by a straight stream nozzle spraying into the slit created by the coulter which were placed 4 in. apart. The latter device offers promise if combined with mechanical cultivation. Wide 26 in. sweeps gave good mechanical control.

Study of powered rotary tillers for soil incorporation of chemicals was continued on a limited scale at Shafter. Improved techniques were devised for studying the uniformity of incorporation with tracers. Results showed more uniform mixing with the knife and angle iron blade rotors than with the tine rotor. Efficiency of mixing was found to increase with the relative velocity of the rotor blade.

Two methods of incorporating fungicides in soil for seedling disease control were found to be superior to the "in furrow" spray at Shafter. A 4-in. wide rotary tiller was used to incorporate liquid and granular

fungicides in comparison with conventional "in furrow" applications of granules and sprays. In final stand counts, soil incorporation of spray and granule formulations of the fungicide PCNB rated first and second, respectively. Granules and spray applied "in furrow" and on the covering soil in the usual manner ranked third and fourth in that order. Spray and granules applied only in the bottom of the seed furrow and the nontreated check ranked last.

The effectiveness of nematocides was increased when combined with precision tillage in California, either as a sidedress application or as a deep application behind the subsoil shank. The latter was better than side-dressing.

3. Studies on mechanical methods of destroying fallen cotton squares were conducted at the Boll Weevil Research Laboratory, State College, Mississippi. An experimental, tractor-mounted, flail-type machine was designed, constructed and tested to determine its effectiveness for boll weevil control. Few major mechanical difficulties were encountered during the field test period. The overall square pickup efficiency for the testing season was 84.2 percent. The efficiency in the cotton middles was 92 percent, and in the drill area underneath the plants, 63 percent. The boll weevil control which was obtained was comparable with insecticide treatments as long as the migration of the insect was not a factor in the experiments. An improved model of the experimental machine is presently under construction. The major improvements include rotary brushes for moving the squares from underneath the plants, and an improved drive for the machine.

Studies on the effects of middle flame cultivation on the immature boll weevil were conducted at State College, Mississippi. Infested squares were treated at various ground speeds with a middle flame cultivator which is designed primarily for weed control. The flamer was tested using one burner (2 nozzles) following by a 16-in. hood, one burner followed by a 34-in. hood, and 2 burners and hoods in series. Significant reduction in boll weevil emergence from the treated material was obtained at low ground speeds with each burner and hood arrangement. The highest ground speed which gave a significant reduction was 1 MPH with 2 burners and hoods in series.

Studies on the effects of sunlight on fallen cotton squares were conducted at State College, Mississippi. Fallen squares were collected and samples were placed in locations so that each would be exposed to either total shade or total sunlight from 10 a.m. until 3 p.m. Samples were placed on black painted soil as well as unpainted soil. No significant differences in boll weevil emergence were obtained.

F. Insect and Disease Control by Ground Equipment in Vegetables and Other Low-growing Crops.

1. Both hydraulic and air blast sprays were applied to sugar beets in cooperation with the Ohio Station and Northern Ohio Sugar Company. Hydraulic applications were designed to study seasonal timing of spray applications, effect of interval between applications, various copper and oil combinations, and control achieved by other fungicides. Results were obscured by dry weather which prevented disease development. For example, although seven sprays of a copper and oil fungicide, beginning July 16 and applied at 10-day intervals, gave the best disease control, the yield of beets and sugar was no better than five sprays applied at 15-day intervals or three sprays at 20-day intervals.

A series of seven different air blast sprays were applied to sugar beets at 10-day intervals. Variations included gallonage applied, swath width, fungicide used, and operating pressure. Dry weather permitted little development of Cercospora leaf spot infection in the beet foliage. All treatments, therefore, gave excellent control of this disease. Manzate and copper with oil applied at comparative rates, showed a slightly higher sugar yield in favor of the former. Copper analyses were made of deposit samples taken across a 100-ft. double swath sprayed from both sides. These show a higher center deposit at a 40 gal. per acre application rate, when compared to rates of 20 and 10 gal. per acre. Other sample analyses show deposit patterns are affected by size, number, and placement of nozzles and by wind velocity and direction.

Sprays were applied to sugar beets at another location to study the effect of supplemental oils in improving the fungicidal action of fixed-coppers. The experiments indicate that increasing quantity added or viscosity of the oil, within the limits studied, increased the adhesion of copper to this foliage.

Sprays were also applied to a mixed vegetable planting to study spray adhesion on various types of foliage (pubescent or glabrous). The effect of dew and rainfall was included in this study, but extreme dry weather interfered with this part of the experiment. The results suggest that smooth foliage should be sprayed more frequently and with a higher dosage than hairy foliage, to obtain comparable disease control.

G. Aircraft Equipment for Application of Pesticides to Vegetables and Other Low-growing Crops.

1. Major project activities in 1963 included the rebuilding of a Bell 47D1 helicopter which was obtained by transfer in 1962. Operations consisted of dismantling all major components, sandblasting, overhauling, inspecting for flaws, painting and rebuilding the entire unit. Spray equipment was designed, fabricated and fitted to the helicopter and will be used in the research investigations. In February and March of 1963, an aircraft

mechanic and machinist, and an aircraft pilot, attended schools for helicopter mechanics and pilot training, respectively.

A series of bait insecticidal sprays were applied with the Rawdon T-1 airplane to a crop of peas for the control of the pea weevil in canning peas. These applications were made near Woodburn, Oregon, in cooperation with the Entomology Research Division. The flight elevation was about 25 ft. and the swath spacing 50 ft. The bait sprays consisted of brown sugar mixed in water and endosulfan or malathion and applied at the rate of 4 gal. of formulation per acre. The object of the tests was to control the insect with a minimum amount of toxicant by use of an attractant bait. In one test area the results were inconclusive. In another area 84 to 93 percent control was obtained at 48 hrs. after the application. The tests showed that the bait spray will suppress the pea weevil population on canning peas although not 100 percent was obtained.

Assistance was given to the Forest Service in conducting exploratory spray distribution tests with a helicopter owned and operated by Evergreen Helicopters of McMinnville, Oregon. The results of these pattern studies were used by the Forest Service as a basis for a series of aerial pesticide application tests with helicopters to control the Western Hemlock looper in Pacific County, Washington.

A spray distribution test series was conducted in cooperation with the Piper Aircraft Corporation using a Piper Pawnee PA-25-235 furnished by the Company. These data showed that a reasonably uniform and satisfactory deposit pattern as well as swath width could be obtained with a low density application rate (1-3 gal. per acre) when an asymmetrical nozzle arrangement was used. A satisfactory deposit pattern was not obtained for the high density applications. Tests were discontinued when the aircraft was recalled by the Corporation because of other commitments. These high density tests will be continued as opportunity permits.

A limited number of tests were conducted with a Piper Pawnee PA-25-235 aircraft owned by Sam Whitney of Newberg, Oregon. This aircraft was equipped with a hydraulically driven spray pump instead of the externally mounted windmill type drive and external mounting used by Piper Aircraft. The change in pump mounting did not appear to affect the spray pattern being deposited.

#### H. Aerial Spray Equipment for Forest Insect Control.

1. Since a helicopter was not readily available at Beltsville, some spray studies were made in cooperation with the Forest Service, using a PA18A fixed wing airplane at 45 to 50 m.p.h. to simulate helicopter application. The degree of spray atomization is an important factor affecting the distribution and effectiveness of aerial sprays. There is considerable information on the atomization produced by various nozzles on fixed wing aircraft but for helicopters such information is very limited. Two flat

spray pattern nozzles, T8004 and T8006 (Spraying Systems Co.) with flow rates of 0.4 and 0.6 g.p.m. were used with the orifice directed forward and down about 40 degrees to the thrust line of the plane. The atomization was 176 microns mmd from the former and 179 from the latter - no significant difference. About this same atomization (180 microns mmd) was produced by a hollow-cone nozzle, D4-25, with an output of 0.29 g.p.m. The orifice was also directed forward and down 40 degrees. Thus, for this atomization of 176 to 180 microns, the flat spray nozzles would be preferable to the hollow cone nozzles because a smaller number of them would be required to provide a given output.

On the studies with heavy aircraft a series of flights were made with a TBM airplane at 200-ft. altitude to study spray distribution from this height as compared to that from lower heights (100 to 150 ft.). Flow rate of the plane was 107 g.p.m. for an application of 1 g.p.a. over a 300-ft. swath at 170 m.p.h. Based on a total of 20 flights, 10 at each height, there was no difference between the two heights at the 0.25 g.p.a. deposit level. At deposit levels of 0.1 and 0.2 g.p.a. swath width was slightly greater at the 200-ft. height but the reverse was true at deposit levels greater than 0.25 g.p.a. These tests showed that the present recommendations of a 300-ft. swath for a TBM will result in a deposit of not less than about 0.15 g.p.a. over this width. Considering overlap of adjacent swaths, deposit should be adequate for control of most forest defoliators. The average spray recovery was 73 percent.

A pilot test of an aerial application of B. thuringiensis, a biotic insecticide, was carried out for control of the gypsy moth in New York State. A Piper PA18A was used to apply 2 gal. per acre using a 75-ft. swath width. A one percent concentration of a water soluble fluorescent tracer, Laucophor C 6202 (Sandoz Chemical Works) was added to the spray mix. Samples of the spray were collected on white Kromekote cards placed in the plots. After spraying, the cards were irradiated with ultraviolet light. The tracer was found to be a very good indicator of spray deposit. The application reduced gypsy moth populations but did not effect acceptable control. No further large scale field applications of this material will be made until additional laboratory work is done to improve its toxicity.

The development of methods for measurement of spray deposit by use of fluorescent tracers has been continued. Attempts are being made to quantitatively assess spray deposits on paper cards. Position and intensity of ultraviolet excitation source has been studied and an enclosure constructed in which sprayed card samples can be assessed. Calibration work is in progress. The measurement of water sprays either by fluorescent tracer or estimation from dyed card standards is an important problem to be investigated during the coming year.

## I. Equipment for Brush Defoliation.

1. Research is underway in cooperation with the Crops Research Division, for the Department of Defense, on equipment and techniques for applying herbicides to tropical and sub-tropical forest areas. An agricultural engineer was transferred to this project at Mayaguez, Puerto Rico in July, 1963. Since that time the engineer has visited most of the research projects of the Agricultural Engineering Research Division that are working on pest control equipment, and has made progress in preparing facilities and assembling needed equipment. Progress has been made in Puerto Rico on a cableway with traveling cart to dispense tracer materials for simulating the application of herbicides by aircraft. The forest cover on the site is varied and, although not continuous, has 3 stories of cover. The largest trees range from 50 to 60 ft. in height; a second group ranges from 25 to 40 ft., and a third group from 5 to 15 ft. Another agricultural engineer was transferred to this project March 1, 1964, with headquarters at College Station, Texas, for research on the engineering phases of the work there.

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#### AREA 4: CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, only recently initiated, has already resulted in sizeable cost reductions, but the potential savings for these crops and vegetables are enormous. Tobacco requiring over 400 man-hours per acre currently, also has long needed mechanization.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

#### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is being conducted at Lake Alfred, Florida; Davis and Riverside, California; in cooperation with the respective State Experiment Stations. Equipment for cotton harvesting is under study at State College and Stoneville, Mississippi; Auburn, Alabama; Lubbock, Texas; and Shafter, California; in cooperation with USDA Cotton Ginning Laboratories and the respective Experiment Stations. Research on deciduous fruit harvesting equipment at East Lansing, Michigan; Wenatchee, Washington; and Davis, California; is cooperative with the Experiment Stations in those States, and with producers, and machinery manufacturers. Crops under study include: Apples, pears, peaches, apricots, plums, grapes, blueberries, cherries, and dates. Development of new techniques for harvesting forage is underway at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Georgia Experiment Station. Research on forage seed harvesting is underway at Corvallis, Oregon, in cooperation with the Oregon Experiment Station, farmers, and industry. Long fiber crops harvesting research at Belle Glade, Florida, is cooperative with the Everglades State Branch Experiment Station. Research on oilseeds and peanut harvesting equipment and methods is cooperative with the Experiment Stations at Stillwater, Oklahoma (castor beans); Bogalusa, Louisiana

(tung nut); and Holland, Virginia (peanuts). Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minnesota. Equipment and methods for harvesting sugarcane are under study at Houma, Louisiana, in cooperation with the American Sugar Cane League. Tobacco harvesting research is conducted cooperatively with the Experiment Station at Lexington, Kentucky.

A contract with the University of Sao Paulo, Brazil, provides for investigations in mechanization of sugarcane production. Its duration is for five years and involves P. L. 480 funds with approximately \$49,000 equivalent in Brazilian cruzeiros.

The Federal engineering effort devoted to research in this area totals 29.0 professional man-years. Of this number 4.0 is devoted to citrus; 5.9 to cotton; 5.5 to deciduous fruit; 1.5 to forage; 1.5 to forage seed; 1.5 to long fiber crops; 3.6 to oilseeds and peanuts; 2.0 to potatoes; 1.0 to sugarcane; 2.0 to tobacco and 0.5 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Most of the state agricultural experiment stations are engaged in some aspect of basic or applied research which is concerned with improving machines and methods for efficient harvesting and farm handling of the many economic crops which make up the total national agricultural production. Much of this research effort is cooperative with the Department.

Detailed investigations are in progress to develop reliable mechanical harvesting and handling equipment as well as ways in which improvements might be made in crop production systems to increase yields, product quality and overall efficiency.

Current research is concerned with the diverse problems involved with these specific crops: All small grains, including rice and field corn; cotton, peanuts, castor beans, and safflower; citrus, apples, peaches, olives, apricots, cherries, prunes, cranberries, coffee, grapes and pecans, green-cut forages, hay and seed crops; cabbage, lettuce, asparagus, tomatoes, Irish potatoes, sweet potatoes; blueberries, peas and sweet corn; tobacco; and sugarcane.

During the course of these engineering investigations close cooperation is maintained with research scientists who have responsibilities for making improvements to these crops. This activity is most important in order to have machines and systems that are compatible with the new developments.

A total of 44.2 man-years is devoted to this work.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Citrus Harvesting Equipment

1. Harvesting citrus. Over fifty million dollars is paid to workers who hand pick the citrus crop. The rapidly decreasing availability of suitable labor for picking citrus has created a serious need for improved methods and equipment for harvesting this crop.

In Florida tree plots were leased for a 5-year period for fruit harvesting studies in the Lake Wales area where damage from the December 1962 freeze was not extensive. Tree shaking trials were conducted on Pineapple oranges and Marsh grapefruit to determine the effect of time of harvest on fruit removal throughout the season; effect of shaking stroke and frequency on fruit removal; effect of fruit hanger length on removal; and effectiveness of a chemical loosener on fruit removal by shaking. A commercial tree shaker, mechanized catching frame and handling system were studied. Variables measured for comparative purposes and future design criteria were: shaking amplitude and frequency, percent solids and acids in the fruit, and bonding force of fruit to stem. Fruit removal ranged from 77 to 91 percent in Pineapple oranges and from 89 to 95 percent in Marsh grapefruit. Oscillating Air Blast trials were made with the air machines previously developed by the Citrus Experiment Station and prototype oscillating air machine loaned by Food Machinery Corporation. Comparative studies were made of different air oscillating mechanisms to determine the most efficient shaking action in terms of fruit removal. Harvest tests were made to determine the optimum air velocity and exposure time of the tree to the oscillating air. An air velocity of approximately 125 m.p.h. at a machine ground speed of one-fourth m.p.h. provided the best fruit removal but caused the most severe leaf damage. Fruit removed in this trial averaged 74 percent in Pineapple oranges and 80 percent in Marsh grapefruit. A catching frame was constructed to work with this continuous type harvest system. Rotating Auger Spindles previously tried by a cooperating agricultural engineer, Florida Citrus Commission, were remounted and briefly tested. Considerable work was done to design and mold new auger configurations from room temperature curing plastics because of poor service life of the previous hand made neoprene augers. Several commercial picking aids for positioning the fruit picker in the tree were observed but none were developed to the point where they could be evaluated by project personnel. Field handling of pallet boxes was observed and a time study made on a "Lightning Loader" boom lift mounted on a "goat" truck. The loader boom, employing a grapple-type lift raised the wooden pallet boxes by the top onto the "goat" bed. This is a versatile system with a minimum of equipment. Work on all of the above harvesting methods will continue in order to determine their effects on tree growth, fruit yields, and need for changes in cultural practices.

In California, the characteristics of electrical conductance, back scatter of nuclear emission, surface temperature and light reflectance was measured for fruits and other parts of the tree to determine their effectiveness as

differentiating features. The studies indicate that there is not sufficient difference in temperature and electrical conductance between fruit and leaves, etc. to be used in selection. The preliminary investigations of back scatter and light reflectance appear worthy of further investigation. Depending on the direction of pull the form of separation were noted to be: (1) Perpendicular to the stem axis, without the button; (2) colinear with the stem axis, a variation of above the button and below the button with some plugging; (3) twisted about an axis perpendicular to the stem axis, without the button; and (4) twisted about the stem axis, above the button. Forces that resulted in removal for these different tests were measured. Tests were performed to determine the extent of damage incurred by oranges in falling through the tree from the point of attachment onto a special catching cushion at the ground. A later test was conducted on pruned and nonpruned trees. Results so far have not been conclusive.

## B. Cotton harvesting equipment

1. In a continuing study of harvest aids in California, cotton was artificially wilted by applying a desiccant and harvesting 48 hours later. This treatment had no advantage over regular defoliation nor regular desiccation.

In a topping and vertical pruning test in Mississippi, both treatments reduced boll rot slightly but also reduced yield. Although there was no lodging problem this year, topping and vertical pruning permitted more sunlight to reach the inner areas of the plants for the first two weeks after treatment; however, there was evidence that more new growth occurred in the topped plots.

In further study of bottom-defoliation and bottom-picking methods at Stoneville, grid bars were constructed to keep the cotton from contacting the top eight rows of spindles. This method allowed about 2 inches more clearance for the plant and overcame the stalk breakage experienced with the spindle shield; however, the Ret Bar pressure plate gave the highest picking efficiency. Bottom defoliation was fairly effective this year, but the extremely dry conditions made it unnecessary in most fields. The Rust picker was used in this test by removing the top crowder channels and opening the top of the unit. This is a very good method of bottom-picking with this machine. Bottom defoliation and bottom picking resulted in a sample with lower trash and moisture content than regular picking.

A number of studies have been conducted to determine the effects of grass on the quality of machine-picked cotton. Results vary with areas, types of grass, degree of infestation, growing conditions and other factors. For the second year cotton was picked from moderately grassy and clean fields at Stoneville with no important quality differences when picked with a tapered spindle machine. Most of the late maturing grass had become etiolated by picking time. The cotton was ginned both with and without lint cleaners and spinning tests will be conducted to determine the effect of grass on

the yarn. Harvesting efficiency was lowered slightly in the check plots where grass and vines infested about 25 percent of the hills compared with less than 5 percent infestation in the treated plots.

2. Cotton picker head torque requirement tests were continued at Stoneville with five greases. These five greases were used in temperatures at 32° F. or below for 30 minutes running time. A high torque measurement of 40 horsepower to start one picker head was recorded at the lowest temperature. A picker with grease-lubricated spindles was serviced and samples taken at regular intervals while picking to determine the amount of contamination on picked cotton. Six samples and a hand-picked check were ginned and determinations of oil content made. After 3 hours, the machine-picked cotton had very little more oil than the hand-picked check. Most of the grease seemed to be dispersed during the first hour of picking. Although lint color was adversely affected, there were no adverse effects from the grease on spinning and fiber properties.

A number of picker attachments were evaluated at Stoneville. A different type of plant lifter device, consisting of longer lifters with rubber tips that pick up low limbs, slightly increased the picking efficiency of a two-row picker. Behind the lifters are wheels with rubber lugs that lift the ground cotton and lower limbs. Additional wheels that replace the shields are also available for late picking and gleaning. These units increased picker efficiency from 88.3 to 91.8 percent and picked up 0.2 bales per acre after the cotton had been picked for the last time. Several of the attachments for scrapping cotton from the ground along with the final picking were in use and were successful in most cases; however, considerably more trash was usually added to the machine-picked cotton and the picker parts are subjected to more wear. A device which automatically adjusts the picking unit height on a two-row picker seemed to work satisfactorily in the field, after minor changes were made. The Ret Bar compressor sheets increased the picker efficiency over the standard compressor sheets.

The spinning performance of cotton harvested with three types of picker spindles was compared in the last year of a 3-year study in California and Mississippi. Less trash was harvested with the smooth square spindle machine. The number of ends down per thousand spindle hours and manufacturing wastes were slightly lower for hand-picked cotton at both locations; however, the classers grade of hand-picked cotton in Mississippi was one grade lower than for any of the machines. Complete reports on these tests will be published in the coming year.

Cotton gleaning machines were used over a wider area this year because of high yields and good salvage operating conditions, often yielding a bale on 4 to 10 acres. Ginning was still the greatest problem of gleaned cotton even though grades and prices were good. In a California test, the efficiency of a notched belt gleaner was found to be constant over a speed range of 3 to 6 m.p.h. Seed cotton trash decreased as forward speed increased.

Four varieties were grown for stripper harvesting in Mississippi. Two storm resistant varieties with 50,000 and 100,000 plants per acre, grew a small stalk and harvested very well before frost with a flexible roll stripper. The open boll varieties were planted at 60,000 and 85,000 plants per acre. They grew to a height of 48 to 60 inches and did not harvest efficiently with the stripper. Yields of the four were 1.5, 1.7, 1.9 and 2.0 bales per acre, respectively, for Arkansas stripper 60-2, Lankart 57, Rex smooth-leaf and Stoneville 7A varieties. This year's results indicate that a smaller, early-maturing, high-yielding plant with good fiber characteristics will be needed for stripper-type harvesting in the sandy loam soils of the mid-south.

3. A broadcast finger type stripper was developed at Lubbock and mounted on a cotton picker chassis for harvesting the broadcast planted cotton which has been successfully grown for several years in the High Plains area. This machine performed satisfactorily in broadcast cotton and in other row spacings from 5 to 40 inches. The USDA green boll separator was designed into the elevating system of this stripper. Power measurements on the improved green boll separator were made with strain gages and associated recording equipment in comparison with the conventional stripper elevator. Horsepower requirement for the experimental unit was about five horsepower more than for the conventional elevator. This additional power is required for air velocity.

4. Sources of trash studies were continued. In Alabama, cotton from plots where the leaves, ground trash, and boll bracts were removed had one-half as much fine trash as cotton from defoliated plots, one-third as much as cotton from defoliated-desiccated plots, and two-thirds as much as hand-harvested cotton. In the well-defoliated cotton, the trash in the harvested cotton consisted of 19 percent leaves, 14 percent bract, 3 percent stems, 58 percent burs, 6 percent unknown trash, and no ground trash. Desiccation of second growth increased the total and fine trash of both the wagon sample and the ginned lint.

Machine-picked cotton was composited and stirred in the trailer prior to cleaning and ginning to determine if such procedures would affect lint quality by mixing the trash which accumulates in the rear of a picker basket. No practical advantages were obtained. Since repeat results were obtained in the 2 years of study, no further work is scheduled under this project at Stoneville.

5. The basic study on the influence of plant characteristics on mechanical harvesting was continued at Auburn. Mechanical picker losses averaged 20 percent for bolls on limbs originating within 4 inches of the ground, 14 percent on limbs originating between 4 and 20 inches, and 8 percent from limbs originating above 20 inches on plants averaging 36 inches high. Horizontal boll location with respect to the vertical stem of the plant had little effect on efficiency. A 2-inch increase in drum height above the ground surface reduced machine efficiency 4.3 percent in a 20,000 plant

population. The laboratory picker was modified and the relationship of spindle speed and picking efficiency was determined for one boll type. For spindle speeds of 700, 1,500, 1,900, 2,300, 2,700, 3,100 and 3,900 r.p.m., the efficiencies were 65, 88, 92, 97, 97, 98 and 94 percent, respectively. Preliminary data indicate that a 5-lock boll is picked more efficiently than a 4-lock type. Also, bolls pointing downward are picked more efficiently than bolls pointing upward. A torquemeter proved unsatisfactory for measuring the force to remove cotton from the bur. A pendulum was designed and constructed for measuring picking energy and measurements are being made of bolls from different varieties, but no data are yet available.

In a similar study at Stoneville, a different type of instrument was used to measure the force required to remove a lock of cotton from the bur. The carpel angle of each boll was also measured. Bolls from each of six varieties over a 3-year span were included in the test. Lankart 57 required the most force, while D & PL Smoothleaf required the least. There was no significant correlation between force and carpel angle although the force was greater for the low carpel angles in most cases.

In a continuing harvesting evaluation of six widely different varieties in Mississippi, conditions were more uniform and efficiencies higher than in the past. Lankart 57 continued to have very little preharvest loss and a lower picker efficiency than the others. The Acala variety produced more cotton than previously on a smaller stalk. D & PL Smoothleaf had the highest picking efficiency and lowest trash content but was highest in preharvest loss.

6. In field storage and handling work at Lubbock, a dump trailer, operating behind the stripper, eliminated the need of men in the trailer and proved to be a satisfactory method of dumping machine-stripped cotton for field storage. A study was made to evaluate the time and motion of this and other methods of handling machine-stripped cotton from harvesting to ginning. A tractor-mounted basket used in conjunction with the USDA boll separator-elevator also gave favorable results in these studies.

### C. Deciduous fruit harvesting equipment

1. About 225,000 tons of Concord grapes are produced each year in the six States of New York, Michigan, Washington, Pennsylvania, Arkansas and Ohio. Conventional harvesting and handling methods are expensive and cause considerable damage to the raw product. A report was published on the development of a machine for picking up field boxes of grapes. Both Bacos and Concord varieties of grapes were picked in half-bushel baskets and transferred in the vineyard to pallet boxes holding approximately 850 pounds each. The study showed that quality was maintained and that \$2 per ton was saved in handling labor. Also, there were substantial savings in container costs and congestion was eliminated at the processing plant. A report on this work is being prepared.

2. Harvesting clingstone peaches and apricots. It is predicted by many experts that hand labor for harvesting tender flesh fruits will not be available in the near future. Previous research showed that mechanical shakers were feasible, provided yields and quality could be maintained. Four acres each of two varieties were harvested mechanically by research personnel and five commercial blocks were harvested by growers using commercial equipment. Data were obtained on yields, fresh fruit quality, canning grades, and harvesting rates and costs and compared to checks harvested by hand. In orchard No. 1, 97 percent was recovered by hand harvest compared to 86 percent by machine harvest. When fruit damage was included, 91 percent was graded No. 1 fruit for hand harvest, whereas 75 percent was graded No. 1 for machine. In orchard No. 2, 94 percent and 88 percent were recovered by hand and machine, respectively. Eighty-two and 74 percent were graded No. 1 by hand and machine. A large part of the difference in the amount of recovered fruit was primarily due to fruit left in the tree. More fruit was bruised by hand picking than by machine, indicating that the padding and decelerator strips did an effective job. However, this was more than offset by the greater number of cuts in machine harvest resulting from fruit falling through the tree. Modifications in tree training and pruning may minimize this damage. Cost per ton of No. 1 fruit for hand harvest was calculated to be \$11.05, whereas cost per ton for machine harvest for yields of 10, 15 and 20 tons per acre were \$11.45, \$7.65 and \$5.70, respectively. If the equipment is used on a two-shift basis, corresponding costs would be \$8.80, \$5.85 and \$4.40. Adding the loss of fruit of 5 and 10 percent for a 15 ton per acre yield, the cost would be \$10.15 and \$12.65.

3. Mechanical thinning of peaches. Hand-thinning of peaches and apples is expensive and labor consuming. Chemical thinning of peaches and early variety apples is considered impractical by most growers because of the inconsistency of the results. Tree shakers are now available for harvesting some fruit and they can be used for thinning. Michigan peach growers thinned approximately 500 acres of peaches with machines in 1963. The savings, in many cases, amounted to \$50 per acre. Studies showed that there was no significant reduction in yield when machine-thinned trees are compared to hand-thinned trees. Another study showed that cumulative bark damage, up to this point at least, has not been serious. This project is being closed out.

4. Dates grow on palm trees which are 30 to 60 feet high and it is becoming difficult to find workers to hand-pick fruit in these tall trees. Refinements were made on the mechanical harvesting and bulk handling systems developed on this project last year. In Fiscal Year 1964 the systems were used in harvesting over four million pounds of dates. (Two years ago all dates were hand picked and handled in small containers.) Where large acreages are harvested, costs are reduced over 50 percent and labor requirements reduced to one-fifth of conventional harvesting requirements. A new system of harvest in which dates are removed on the tree without cutting the bunch from the palm was tested and shows promise. The hand-carried vibrator designed and constructed for this work removed 100 percent of the dates from a mature bunch in less than three seconds.

5. Apples bruise easily and must be handled with care when harvested for fresh market. This type of picking is difficult, time consuming, and it is becoming difficult to recruit labor. Techniques and machines which will make it easier and less costly to harvest apples for fresh market are needed. In Washington, a fruit conveying mechanism was developed for attachment to a commercial self-propelled tree "working" machine. With the aid of the machine and its attachment, the picker can position himself at the optimum picking location, remove the fruit and place it in the waist level receiving trough for delivery to the bulk bin and subsequent distribution within the bin. Increased picking efficiency was obtained and comparative time studies showed that picking Red Delicious and Winesap apples from the machine yielded increases of 18.4 and 34.7 percent, respectively, over the ladder picking rate. Bruise damage obtained with the experimental conveying system was compared to that received in the conventional ladder and bag system. Increases of 4.0 and 15.5 percent were obtained in Red and Golden Delicious varieties, respectively. Drop tests indicated that a decelerating medium consisting of a one-inch thick mat of open cell polyether foam, covered with a 2-1/4 inches of water, could be used to collect free falling apples. No bruising of fruit occurred when using this combination to stop Golden Delicious apples falling 16.5 feet.

6. Over 35 percent of the apples produced in the United States are now processed. Growers only receive 80 cents to \$1 per bushel for apples and profits are small. Present picking costs of 20 to 25 cents per bushel need to be reduced. In Michigan, an experimental catching frame which would collect (with a minimum of bruising) apples harvested with tree shakers was constructed. In September 1963, five 24-bushel bulk boxes of McIntosh apples were harvested with an inertia shaker and catching frame. On October 17, four bulk boxes of Northern Spys were machine picked. These apples, along with hand-picked check lots, were trucked more than 100 miles to a CA storage and held until April 4, 1964. McIntosh and Spys are both tender varieties and the over-six-month storage resulted in a severe test. The McIntosh apples were graded and packed into three-pound poly bags on April 13. The mechanically-harvested McIntosh apples resulted in a 32 percent less pack out than the hand-picked fruit. However, almost all of the apples that did not make number one grade were suitable for processing. Next year similar studies will be made with the exception that some of the apples will be processed immediately and the rest processed after a three-month storage period. In Washington, a limited shake test was made on Red Delicious apples to determine the type of fruit separation which might be expected with shake harvesting. Separation acceptable for fresh market fruits was obtained in 65 percent of the manually shaken sample. Construction of a mechanical inertia shaker for further experimental work in this area is underway. The above tests indicate the possibilities of harvesting apples for processing outlets and also for fresh market outlets when labor is very critical.

7. Standard apple tree shape and size is about as ineffective for mechanized harvesting as could be designed. The tree walls of standard trees

planted 12 feet apart in a row and the rows 18 feet apart were over 6 years old and yielded over 600 bushels per acre. Time and motion studies of picking will be made during next harvest and compared with picking conventional trees. The apple and peach trees were hedged for the third straight year and no significant yield differences were obtained.

8. Cultivated blueberries are grown commercially in the Mid-Atlantic States, Great Lakes area, and the Pacific Northwest. Although this project has developed equipment and methods which greatly reduce the cost of harvesting and packing blueberries, costs are still rather high. A continuous-type blueberry harvester should reduce picking costs even further. The experimental unit for testing a principle of continuously harvesting blueberries mechanically was constructed and field tested. The results indicate that as far as fruit removal is concerned, the machine is satisfactory. Considerable time and effort will be required to perfect a prototype machine, however.

9. From one-third to one-half of the gross returns of both sweet and sour cherries are paid to the workers who harvest the crop by hand. These workers are becoming increasingly hard to recruit; a situation which exists in all cherry-producing areas. The purpose of the research is to reduce the harvest costs and labor requirements through mechanization and at the same time maintain quality of the fruit. Multi-purpose fruit bulk boxes were tested with cherries and peaches. These boxes, which contained hinged, horizontal partitions, can be used effectively on soft fruits which cannot be handled at depths of more than 8 inches in conventional or shallow bulk boxes. Sweet cherries were again handled successfully in bulk boxes at depths of 16 inches for brine outlets and 14 inches for canning outlets. A report of this work was published. Electric sorting machines used for the first time were evaluated. A report was made available. With improvements they should reduce the number of workers needed and also reduce costs. Last year the units cost the processors about \$1 a ton more than hand sorting. They proved effective in removing decay and scald defects but did not remove stems or light cherries. Design data on construction of destemmers for tart cherries was obtained by evaluating commercial destemming units for sweet cherries. A tart cherry destemmer has been designed and is under construction and will be tested next summer. The studies on cushioning materials and terminal velocities were completed and separate reports prepared for publication. Urethane foam is a good all-around cushioning material. A hydrocooler for cherries has been designed and is being constructed. It has a theoretical capacity for reducing the temperature of two tons of cherries from 80° to 32° F. per hour. It will be used to hydrocool over 50 tons of tart cherries.

10. Harvesting prunes. Although research on this project has led to the adoption of mechanical harvesting in the Sacramento Valley, prunes are still harvested by hand in the Santa Clara Valley where prunes fall to the ground as they mature over a month period. Work on this project during 1963 concentrated on the evaluation of the use of pickup machines. Tests were

conducted on two soil types--loam and gravelly loam. The orchards were only rolled but the use of a landplane operation is advised and would have eliminated some fruit loss and dirt and clod pickup. Results show that prunes can be picked at an average of 60 trees per hour, assuming four passes per tree. A yield of two-thirds box per tree resulted in 40 boxes per hour. Lug box handling required two men for the pickup operation and one man to operate the shaker for an output of 13 boxes per man-hour. Bulk handling would reduce the crew size to two men, resulting in an output of 20 boxes per man-hour. A pickup machine operation appears to be the harvest method with the least risk. Although the pickup method is not the ideal solution, its use involves fewer potential problems than either the shaker and catch frame or the pulsating air methods. The major drawback of this lower risk operation is the land preparation which must be done carefully for successful harvest.

11. Bark damage can be a serious problem when tree shakers are used to harvest or thin fruit. In California, research initiated in 1962 was continued. This included a study of the forces developed while shaking various size limbs, the maximum stresses that cause bark injury, and possible methods of attachment for shaking that would not exceed these allowable stresses. No appreciable difference was observed in the effect of contact area on the stress causing browning at the cambium. This occurs in the range of 575 to 600 p.s.i. Results on the effect of limb size show that the stress exerted on a small limb is substantially greater than on large limbs. The reason for this is that the area of contact is reduced in greater proportion than is the total force exerted from large (5-1/2 inch) to small (1-1/2 inch) limbs. The 1963 belt-type clamp was modified to improve pad stability by relocating the pivot point to an effective location where the belts contact the limb. In tests it was found that when the shaker axis was 25° to 30° away from perpendicular to the limb, the bark was sheared in a longitudinal dimension. (This problem was not encountered in 1962--the pads were unstable at these angles and it was not possible to conduct this test.) No damage occurred either radially or tangentially. In analyzing the problem it was found that when a tight grip is made on the limb the longitudinal force component exceeds the yield strength of the bark and failure occurs. If only a snug grip is made, the belts can move relative to the bark and only scuffing of the bark occurs. This is not a practical solution since variation in bark smoothness would require different clamping pressures. A number of possibilities are now being considered for future work on this project. In Michigan, a new type C-clamp for tree shakers, having five prongs on each face, was designed and constructed. The prongs will penetrate into the heart wood as the clamp is closed. The clamp will not slip or tear the bark. It will, however, puncture the bark in ten places and the significance of this type of damage will have to be evaluated.

#### D. Forage harvesting equipment

1. Field-curing studies of Coastal bermudagrass show no significant difference in the drying rate between grass conditioned with a crusher, semi-crusher, crimper, or tedded 4 hours after cutting. These treatments did dry faster than unconditioned hay without any loss in yield. Hay cut with a rotary mower dried the fastest but much of the hay was lost by this method. With either of the four conditioning methods, the hay was down to about 18 percent moisture content within 27 to 30 hours after cutting.

2. A stationary hay wafering system was assembled, using an experimental field wafering unit, which permitted more control of rate of feed, moisture content, hay composition and physical form than could be achieved in field wafering. In addition to production tests, this unit was used to produce 65 tons of alfalfa hay wafers for handling and drying tests and for feeding trials. Production tests with this wafering unit showed that it was not possible to obtain uniform die flow and wafer quality when the wafering device was mounted with its axis horizontal, even though individual adjustment was provided for each die. Had all 25 dies been operating as several "good" dies, 7 tons of dense, durable wafers per hour could have been produced.

Tests of the effect of stage of maturity on waferability of second cutting alfalfa hay showed no observable differences. This test, however, did not disprove early observations that more mature hay was more difficult to wafer because the different test hays had similar leaf to stem ratios and were all fine stemmed. This similarity was due to the particular growing weather, cultural practices, and method of harvest (baled and artificially dried) of the test hays.

#### E. Forage seed harvesting equipment

1. Improved techniques for harvesting seed crops. Small grass and legume seed producers in the Willamette Valley, Oregon, are losing more than 50 percent of their crops in their harvesting operations. At Corvallis, Oregon, the 66 percent crimson clover seed loss, shown in a 2-year farmers' survey, was reduced by early harvest, proper machine settings, and forward speeds of the combine. Pure live seed yield was 85.7 percent when using rubber-covered bars and concaves in the threshing cylinder. This compares to 73.9 percent for the spike-tooth cylinder and to 75.6 percent for the angle-bar cylinder. The optimum cylinder concave clearance with all types of cylinders was 1/16- to 1/8-inch. This report concludes a 5-year study in harvesting crimson clover. Farmers have already adopted many of the research findings which has more than doubled their take of pure live crimson clover seed per acre.

Research in birdsfoot trefoil harvest was continued using the conventional windrow drying, then combining, and comparing this to windrowing on clear 4-mil plastic; then using a combine with a special pickup to feed the

material into the combine and rewind the plastic sheet for future use. Windrowing on plastic yielded 23.8 percent more pure live seed than the conventional harvesting methods. One test was to place plastic sheets between the rows of birdsfoot trefoil and wait for complete seed shatter; the other was to windrow the crop on plastic sheets and wait for the seed to shatter and fall onto the plastic. Adverse weather, including frequent rains, ruined both tests. The study will be repeated in 1964.

The 5-year harvesting study emphasizes the inadequacy of the grain combine for use in harvesting small grass and legume seeds. This has prompted the agricultural engineers to give consideration to the design of a different type seed harvester. The preliminary plans are to use a rotary flail-type harvester to cut and remove the seed and forage from the growing field. This will deliver the cut material to a double belt, which, in turn, will thresh or rub the seed out of its pods. Revolving parallel bars will drop the seed and scalp off the straw; the dropped seed will flow by gravity into a two-stage vertical rotary screen that will remove stems and leaves and deliver the seed to a pneumatic separator which will remove light chaffy materials.

The progress on the harvester to date includes: (1) Purchasing a rotary chopper and making preliminary tests by removing crimson clover from the windrow. Eighty-one and five-tenths percent of the seed was saved with only 0.2 percent broken seed and 0.2 percent drop in germination; (2) designing, constructing, and testing a vertical-rotating screen. Preliminary tests indicate that the rotary screen will have several times the capacity of a flat screen and be independent of slope angle; (3) purchasing and testing of a pneumatic separator; and the purchase of a special threshing belt. As soon as all the components are tested they will be worked into a harvesting machine.

2. Optimum moisture content for seed harvesting. At Corvallis, Oregon, time-of-harvest research was continued with bluegrass and orchardgrass. In the bluegrass harvesting research over a 28-day span, the crop was harvested 7 times, starting with a seed moisture of 40 percent and continuing until the seed moisture reached 13 percent. The highest percentage of pure live seed (73.2 percent) was obtained when the seed moisture was 33 percent. This compares to an average pure-live-seed yield of 64.1 percent measured in a farmer's 2-year harvesting survey. Orchardgrass was harvested 7 times over a 25-day period with the maximum pure-live-seed yield of 73.8 percent obtained by harvesting when the seed moisture was 44 percent. This compares to a 55.8 percent pure-live-seed check over a farmer's 2-year harvesting study. The time-of-harvest studies will be continued to obtain enough repeat tests for statistical analysis. The maximum quantity of pure live seed can be obtained by harvesting at the optimum stage of seed maturity.

Research findings indicate that the moisture content of the seed is the most reliable measure of the crop maturity. Since the seed moisture can change rapidly, it is imperative that seed moisture be determined accurately

and rapidly. Two methods of testing moisture that meet these requirements are (1) the use of a portable battery-operated electrical resistance meter used in conjunction with a calibration curve for the crop, and (2) the use of an inexpensive attachment that goes on the exhaust of an internal combustion engine in order to dry the material. The cost of the unit is approximately \$25. With the use of the exhaust from a tractor, automobile, or truck, the unit can measure the moisture content of seed in the field to a  $\pm 3$  percent accuracy in approximately 5 minutes.

F. Long fiber crops harvesting equipment

1. The growth of bamboo planted for the project on harvesting and farm handling equipment for bamboo has been excellent for all varieties on the peat soils at Belle Glade. These plots are being renovated by removing all fallen, broken, or dead culms, grass, weeds, and a variable assortment of tree seedlings springing up in the plantings. A generous application of 0-10-15 fertilizer with minor elements is a part of the renovating program. Planting material has been supplied to various others; also stalk or culm material for plant stakes and other uses has been available. A saw-type harvester for limited use has been planned and will be used at Belle Glade on the Bambusa tuldoidea variety. Growth of most varieties at all other locations has not been up to expectations although limited areas at the Edisto Station are reported mature enough for harvest.

2. The harvester-decorticator built for the sansevieria harvesting, defibering, and fiber conditioning machinery and methods project has been completely rebuilt and is now ready for field testing. The machine is a combination of the sansevieria harvester developed as a result of several years of research and the decorticating unit of the machine built for defibering lecheguilla. It is driven and steered by hydraulic power and has a speed range of from a fraction of a mile-per-hour to 5 or more miles per hour. All of the working parts of the harvester as well as those of the decorticator are hydraulically powered. All parts of the machine are controlled by a single operator. One man and possibly two will be required to handle the fiber as it comes from the machine. All waste material will be scattered over the stubble and root bed as the machine moves through the field. Sansevieria fiber samples have been supplied for various laboratory tests to be made by the plastic and paper industry. Also interest is reviving as to the possibility of the fiber to replace some of the abaca for cordage.

3. Plantings for engineering research on the development of improved harvesting and processing machinery and methods for the production of kenaf and other jute-like fibers were made at Belle Glade, Florida; the Palm Beach County Farm, near Lake Worth, Florida; and at the Georgia Coastal Plain Experiment Station, Tifton, Georgia. A manufacturing test sample of 6,838 pounds was produced at the three locations. This was spun and woven into bags at the Productos de Kenaf S.A. factory in Guatemala. The fiber was rated excellent as compared with that coming to the mill from other

sources. Changes made in the harvester-ribboner included speeding up the ribboning drums, increasing the ground speed, and replacing the worm gear drive on the stalk gathering chains with a ring gear and pinion. As a result of these and other minor improvements, the machine gave a good account of itself under all existing field conditions. Retting tests indicated that although the ribbons retted faster if allowed to sink to the bottom of the canal, superior quality fiber was obtained if they were suspended above the bottom or placed on a plastic lining. Ribbons retted in a concrete tank gave fiber superior to canal retted fiber.

#### G. Oilseeds and peanut harvesting equipment

1. Castor combine for harvesting damp or dry castor beans. Castor beans are left in the field the full growing season to obtain optimum yields. As a result the crop is normally the last to be harvested in the fall and comes at a time of frequent adverse weather conditions--high humidity, fog and wet weather. Since the presently used castor harvesters can be used only when the seed capsules are completely dry, favorable harvesting conditions are limited. Development of a harvester which will harvest castor beans when damp or dry would lengthen the harvest time and permit more acres to be harvested per machine. Research started last year was continued this year. An attachment was developed to harvest closely spaced rows which included 8 rows in place of the usual 4 rows spaced 40-inches apart. In order to facilitate using large wheels on tractors, the rows were paired two 14-inch rows with a spacing of 26 inches between pairs. This study was started to determine the practicability of harvesting close row spaced plants, should increased economical yields materialize from close row plantings. With this pattern of spacing, the combine was maneuvered satisfactorily on four different varieties without seed being knocked off adjoining rows by the harvester.

Development of moving brush row seals. A new principle of conveying loose castor seed into the combine header using moving row brush seals was designed and constructed as an attachment on a regular combine header. The principle proved to be effective and should cost less to incorporate in a machine than attachments now used on commercial machines. A patent application has been filed on the moving-brush principle.

Conditioning castor beans for harvest by chemical defoliation. Castor beans during a late growing season have been conditioned for harvest, with varying degrees of success, by using chemical sprays to dry the seed capsules and defoliate the leaves. The variation in castor bean varieties, as well as weather and crop conditions have shown varying results in effectiveness and requirements of chemical spray material. A varietal trial of castor beans which included 49 hybrids and varieties was successfully defoliated using a chemical "Diquat" with water. The material could not be fully evaluated because wet weather set in and prevented harvesting.

2. Development of tung harvester. The major cost of tung production is in harvesting the crop by the common practice of using hand labor. Dependable labor is becoming scarce and more costly each successive year. Substitution of hand labor with efficient and effective machines could reduce harvesting and handling costs and would result in an orderly harvest. One of the biggest problems in developing an effective tung harvester is the wide range of harvesting conditions which vary from extremely dry and dusty to very wet over widely varying soil and terrain. Design factors affecting the harvester efficiency, cleaning ability, and the operation of the handling of tung from the harvester to the processing plant were studied. More effective conveying equipment was installed on the machine and many parts were simplified. The use of air for disposal of excessive bulk of leaves showed promising results. Further development is needed to make the machine more effective under a wide range of crop, soil and weather conditions.

3. Pruning of tung trees to facilitate the use of equipment in production and harvesting. Tung trees normally produce limbs low to the ground that will prevent the use of machines in production and harvesting without extensive damage to the trees. A study was started to determine the productivity of established trees to pruning of the lower limbs which would permit the effective use of machinery. This experiment will continue for a number of years to fully evaluate the effect of pruning. A similar experiment was started on seedlings to determine whether this type of pruning early in the life of the trees affects the total life production of tung fruit.

4. Peanut digger development. Limited field tests with the project's 1962 model peanut digger indicated that further improvements are needed to eliminate vine wrapping of the upper conveyor. The relatively short conveyor designed for maximum economy did not elevate the vines adequately for an effective transfer onto the soil separators. A small quantity of vines passed between the conveyor and elliptical soil separator assemblies, which was due to the tendency of the vines to wrap. The addition of segmented baffles on the upper conveyor shaft to eliminate vine wrapping was ineffective. Additional changes and tests are planned for improving the digger's performance.

5. Specific gravity and grade of green-harvested peanuts. Repeated tests with samples of green-harvested unshelled peanuts have shown that four different quality grades of peanuts were often found to have the same specific gravity. This characteristic was noted in at least one-third of the different specific gravity categories studied. These data show that separation of immature peanuts from mature peanuts by pneumatic systems of the vacuum or pressure type, or with liquids of varying densities, are not likely to become satisfactory.

Size and grade relationship of green-harvested peanuts. In a study of the diameter-grade relationship of a sample of green-harvested peanuts 46 to 56 percent of the total number of immatures were approximately one-half inch or smaller in diameter. These may be separated by screening with a minimum loss of good quality unshelled peanuts. Remaining immatures and all other

peanuts of economic value in the sample were larger than one-half inch in diameter. In an evaluation of a separation procedure based on length-grade relationship, 25 to 31 percent of the immatures may be removed without a loss of good quality peanuts. Mechanical separation according to diameter may be expected to remove an estimated 50 percent of the immatures. In a combination procedure based on mechanical separation according to both diameter and length, incorporation of the length factor would not increase separation efficiency more than 4 to 5 percent.

Mechanical screening of green-harvested peanuts. Mechanical screening studies were conducted to separate immatures and foreign material from green-harvested peanuts using slotted perforations 5/16-, 3/8-, 7/16-, 15/32-inch wide x 3 inches long. In the order listed, these screens removed 47, 61, 72 and 85 percent of the total number of immatures and 45, 62, 73 and 74 percent of the foreign material by weight. The loss of unshelled peanuts through the 7/16-inch and 15/32-inch screens was estimated to be \$0.32 and \$1.49 per ton, respectively. Primary objection to screening is the potential loss of the loose shelled kernels.

Numerically, the number of immatures in green-harvested peanuts ranged from 15 to 25 percent, whereas peanuts combined after 6 days in the windrow contained only 2.5 to 4.5 percent immatures. The immatures in green-harvested peanuts after drying to equilibrium moisture content (farmers' stock) represented 1.1 percent of the total sample by weight. Those combined after 6 days in the windrow contained 0.35 percent immatures by weight. Green-harvested peanuts contained approximately 2,680 pounds more moisture per ton of farmers' stock peanuts than peanuts which were dried 6 days in the windrow.

Attempted separation of green-harvested immature peanuts from mature peanuts using sensitive pneumatic and electrostatic separators was not satisfactory as the equipment did not make a clear cut separation of the mature from the immature peanuts. An electronic color sorter designed and used for separating low moisture unshelled Virginia type peanuts also failed to make a satisfactory separation.

#### H. Potato harvesting equipment

1. Mechanical injury of potatoes. Bruising continues to be one of the major problems in harvesting and handling potatoes. Studies were made to determine if there was a correlation between difference in physical measurements of potatoes (stress-strain, sheer strength and electrical conductivity) and differences in resistance to mechanical injury. No correlation could be established. Samples of freshly dug tubers were run over a bruising device. Other potatoes were taken directly from the loading elevator of a commercial harvester and evaluated for bruising. These potatoes were tested with an impact instrument. No correlation between the actual bruising and the results with the impact instrument could be established. The cantilever flap rubber cushioning for rod conveyors, given preliminary tests last year, was produced in experimental quantities for use in two commercial

harvesters. One was used for 120 acres and the other for 300 acres. Results showed no design weakness and the use of the cushioning flaps resulted in less bruising and good soil separation.

2. Multi-row harvesting of potatoes. Potato harvesters have become more expensive and heavier each year. Anything which can be done to increase the acreage a unit can harvest and reduce soil compaction is desirable. The 1963 work again showed that combining direct and indirect methods of mechanically harvesting potatoes made it possible to harvest four to six rows at one time. Results show that standard two row open front style harvesters, equipped with two 29 inch or 30 inch primary aprons and two end-to-end roller shares, are adapted to the direct-indirect operation with either two or four rows windrowed between the two rows handled direct by the harvester. Triple apron open front style harvesters are not recommended because the two extra rows of apron hooks increase the hazard for that type of damage on primary aprons, and appear to have lower soil separating capacity than aprons of the same specifications except greater width (longer link span). Total capacity of a given harvester can be reached in a given yield at lower travel speeds which permits the use of lower apron speeds, more soil padding and less roll-back -- all favorable to the reduction of bruising or other mechanical damage. It is estimated that by the combination direct-indirect method, one harvester and a semi-harvester working in favorable conditions can reach a harvesting capacity of 2,000 pounds per minute and that 500 acres per season would be a conservative figure for planning purposes in the Red River Valley.

3. Dust applicator for seed potatoes. Studies conducted by pathologists have shown that cut seed treatment prevents seed piece decay. The application of chemicals by dipping these seed pieces in a solution has serious limitations. Although dusting has many advantages, no commercial equipment for uniform application insuring complete coverage of the seed piece surface is available. A laboratory device for applying dust to cut seed potatoes was constructed. Freshly cut tubers were passed through an atmosphere in which a fungicide dust was suspended. Tests with this experimental equipment revealed that an excessive amount of dust settled in the dirt separation compartment thus involving waste of dust or the alternative of screening the dust out so it could be reused. The unit is being modified so that an inclined rotating drum replaces the oscillating tray as a means of conveying the cut seed pieces.

#### I. Sugarcane harvesting equipment

1. Cutter-cleaner-loader-type sugarcane harvester. The major design and construction changes on the USDA experimental sugarcane harvester consisted of providing a wider range of telescoping header arms and topper clearance. This resulted in more effective and efficient harvesting under a wide range of field conditions and permitted the machine to operate either direction on the rows regardless of direction the cane might be down. These investigations are in cooperation with the American Sugar Cane League who provided some financial assistance and program direction in an advisory capacity.

Gathering assembly for down cane. A telescoping gathering assembly was redesigned with the stroke increased from 19 to 32 inches to provide a wider range and flexibility in gathering down cane. The topper height range and clearance for disposal of tops was increased to assist in preventing chokes under more adverse conditions. These modifications provided more effective operation of the harvester.

Effect of stripper combination in harvester efficiency. Harvester efficiency studies were made on the USDA machine comparing stripper combinations, no strippers, both strippers, only lower strippers and only upper strippers on three varieties of sugarcane. The use of both strippers as compared to no strippers reduced harvester efficiency 3.33 percent (significant at .05 percent level) when harvesting variety CP48/103, second stubble. The harvester efficiency for this variety was reduced 2.28 and 2.21 percent (significant at .05 percent level) for lower and upper strippers, respectively, compared with no strippers. No significant differences in harvesting efficiency could be measured between use of stripper combinations on varieties CP52/68 and CP44/101, both second stubble. The quantity of trash in the harvested cane was reduced 1.98 percent (significant at .01 percent level) when both strippers were used compared to no stripping for variety CP44/101, second stubble. The quantity of trash for this variety was reduced 1.30 percent (significant at .05 percent level) by use of both strippers compared to only upper strippers. The lower strippers reduced the quantity of trash 1.40 percent (significant at .05 percent level) compared to use of no strippers. No significant differences in trash content of harvested cane could be measured between stripper combinations on varieties CP48/103 and CP52/68. No significant difference could be measured as to the effect of yield upon harvester efficiency for the various stripper combinations in yields ranging from 25.5 to 37.8 standard tons per acre.

Harvester efficiencies of 94 to 98 percent have been obtained cutting erect cane. For badly lodged cane efficiencies of 80 to 90 percent have been obtained.

Distribution of trash, cane and sucrose measured in 1-foot increments above the ground surface varied widely between erect and lodged canes. Lodging of variety 58/48 appears to have a depressing effect upon indicated recoverable sucrose. Seventy-seven and eight-tenths percent of the variety CP58/48 was in a zone of 0 to 2.19 feet above the top of the row. The 0 to 2.19 foot zone contained 47.4 percent of the total trash. Separation of the trash from millable cane is the main problem in harvesting badly lodged or recumbent cane. The removal of leaves and tops from a ton of whole cane produced 26.61 pounds more sucrose in the milling process than when the cane was not cleaned.

2. A 5-year contract for investigations in mechanization of sugarcane production was executed in the spring of 1962, under PL 480 funds with the University of Sao Paulo, Brazil. Research is currently underway on two sub-projects.

Minimum tillage in sugarcane. In Brazil, most of the sugarcane is planted after the soil has been plowed approximately 6 inches deep, harrowed, and then furrowed to a depth of about 10 inches in which bottom the cane stalks will lay after fertilization. Two plowings and two harrowings are a common practice but result in high power requirement. Also, the cane stalks lay on a compacted region in the furrow bottom and the initial phases of growing take place under a compacted soil. For the purpose of reducing the total power requirement for seed bed preparation and to study the effect of other practices on yield, tests were conducted in 1963 comparing the conventional method with planting in furrowed plots that had not been previously plowed or harrowed. While production data is not yet available, the following observations have been made: (a) There appears to be no difference in germination between treatments; (b) greater tillering was evident in the plowed plots; (c) at the critical rainfall period, there was no difference in soil moisture between the plowed and unplowed plots; and (d) there was no difference in weed population.

Development of a sugarcane harvester. Sugarcane burning prior to hand harvest is a general practice in the State of Sao Paulo. Based on information from farmers, it was felt that mechanization of the harvesting operation could be made by two machines, one of which should cut the tops and strip stand cane. This stripping unit should work ahead of a mounted cane harvester which would cut the cane at the base and load it on a wagon. These two units working simultaneously in the field would eliminate the burning practice and also simplify the design on the harvester itself. Progress to date includes the mounting of a prototype stripping unit on a tractor to further observe the possibility of stripping stand cane. Wire ropes three-eighths-inch in diameter fastened to a rotor comprise the stripping unit. At a speed of 650 r.p.m., no leaves or trash accumulated around the rotor. Optimum tractor speed was 1.8 m.p.h. The unit was operated on one side of a row of hand-topped stand cane. After several tests, a reasonable stripping job was obtained. However, several problems with the unit include: The wire ropes cause some stalk bruising and their life is short due to the constant flexing.

## J. Tobacco harvesting equipment

### 1. Handling of stalk-cut air-cured tobacco on pallet-rack curing frames.

A conventional barn at the Experiment Station Farm was modified by removing one side and the first three levels of tier rails, and installing adjustable side curtains on the modified side. Thirty-six 6 x 8 x 12 feet steel portable curing frames were constructed. They were filled in the field one day after the tobacco was cut. Three bulk densities were tested; 30, 39 and 48 square inches per stalk in area of frame plan section. The frames were placed into the barn on the tenth day after cutting, being handled entirely by a front-loader tractor. Approximately 18 man-hours per acre were required for housing. Normally 40 man-hours per acre are required during conventional housing. Neither bulk density nor location within the barn had significant effects on quality of the cured product, based on government leaf graders' evaluations.

A harvesting and housing system was proposed in 1963 involving the handling of stalk-cut air-cured tobacco on vertically suspended strings. The system is to utilize a harvester whose function is to mechanically cut the stalks, automatically fasten the base of the stalks at regular intervals to a continuous twine, and convey the "chain" of stalks to a wagon pulled alongside. A portable drum hoist on a rail system at the top of the barn will be used to pull the tobacco from the wagons. Components on the harvester will be pneumatically or hydraulically driven.

Cooperation was continued with the University of Kentucky Agricultural Engineering Department toward the development of a mechanical harvester to cut unprimed tobacco plants and place them on conventional wooden sticks. A spearing mechanism using a "spiral-held floating spear" was constructed and field tested in 1963. Different shielding techniques were tested in an attempt to minimize leaf loss, which was the major problem encountered with the mechanism. This loss of leaves amounted to approximately one leaf per stalk. Improved shielding may decrease this loss by 50 percent.

Tobacco leaf resistance to external force. Engineers who establish design criteria for machines to handle tobacco must consider the plant's resistance to forces exerted by the machines. Of particular concern is the maximum force which the leaf can tolerate without injury or loss of market value. An investigation was continued to define the relationship between leaf resistance to bruising and yellowing time. Four tests were made with an attempt to eliminate or minimize all variables except time of yellowing. Resistance was found to fluctuate considerably during the first 24 hours after harvest, starting at approximately 60 p.s.i., rising to about 95 p.s.i. after 10 hours, then decreasing to 30 p.s.i. after 24 hours where it remained rather constant during the remainder of the testing period of 90 hours. This pattern was consistent for all four tests. Additional work will be required to explain the reason for the variation in resistance.

The strength properties of tobacco stalks are important in the design of machines to handle the crop. Values for modulus of elasticity of the woody portion of the stalk were determined in 1962 for three varieties of Burley tobacco. Work is now being done to determine the applicability of these values to intact stalks. Testing techniques have been worked out for testing intact stalks in flexure to determine modulus of elasticity for comparison with values obtained from small specimens of material sawn from the woody portion of the stalk. Preliminary investigations indicate that values determined from small specimens may be applied to intact stalks.

Stage of maturity at harvest has a considerable effect on the quality of the cured tobacco. An objective means of evaluating maturity is needed by producers and by research workers in order to obtain reproducible results from experiments, especially in curing investigations. A study was made to determine the feasibility of using moisture content of the tobacco plant as an indication of its stage of maturity. Moisture contents of both stalks and leaves were taken periodically over a 4-week period beginning approximately

3 weeks before normal harvest time. Values of moisture content were plotted against time or stage of maturity and equations for the relationships between these variables were determined by regression analysis. However, fluctuations between determinations, due chiefly to rains, resulted in standard errors of estimate which would warn against using moisture content alone as an index of stage of maturity. This does not mean, however, that moisture content and one or more other variables such as soil moisture might not give a reliable indication of stage of maturity.

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AREA 5: CROP PREPARATION AND FARM PROCESSING  
(EXCEPT COTTON)

Problem. The programs of research in this area are concerned with the development of better methods, techniques, and equipment for use on farms for the initial preparation for market or the processing of farm products to increase efficiency in the use of labor and equipment, preserve quality and prevent spoilage and damage from mechanical handling. While considerable information has already been obtained for the development of processes such as drying and separation, basic and more precise information must be developed for these and other processes in order to achieve further progress. The underlying principles that pertain to the cleaning and drying of different crops, curing of tobacco and peanuts, and sorting need to be determined. The methods for processing farm crops are largely dependent on production practices and dictated by future handling or storage requirements. Consequently, this requires interdisciplinary collaboration in the creating of a completely mechanized program of crop production.

USDA AND COOPERATIVE PROGRAM

The Department's effort in this area constitutes a long-term program involving agricultural engineers and statisticians engaged in both basic and applied research on the engineering phases of crop preparation and farm processing. Seed cleaning research is currently being conducted at Corvallis, Oregon, in cooperation with the Experiment Station and private industry. Research on tobacco curing and sorting is cooperative with the Experiment Station at Lexington, Kentucky. The decortivating, retting, and cleaning of long fiber crops is carried on at Belle Glade, Florida, in cooperation with the Everglades Branch Experiment Station, the Office of Defense Mobilization, and industrial fiber users. Research on the drying of grain is cooperative with the Experiment Station at Ames, Iowa, equipment manufacturers, and farmers. Forage processing is under study at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Coastal Plains Experiment Station. Manufacturers cooperate through loan of equipment. Research on the processing of tung nuts is conducted at Bogalusa, Louisiana, in cooperation with the Experiment Station and industry. Drying of castor seed is cooperative with the Oklahoma Experiment Station.

The Federal engineering effort devoted to research in this area totals 12.1 professional man-years. Of this number 2.5 is devoted to seed cleaning, 2.0 to curing tobacco, .5 to decortivating, retting, and cleaning long fiber crops, .2 to drying of castor seed, 4.7 to drying of grain, 1.5 to forage processing, .2 to tung nut processing, and .5 to program leadership.

## PROGRAM OF STATE EXPERIMENT STATION

Many freshly harvested agricultural crops must be subjected to early treatment in order that they may retain as much as possible of their original qualities. The state agricultural experiment stations are involved in both basic and applied research studies which have as their broad objectives the development of improved methods, equipment and techniques for preparation and processing of farm crops to preserve quality and prevent spoiling while in storage.

The scope of the current program may be best illustrated by describing it in broad areas of study.

Drying or curing investigations are in progress on forage crops, cereal crops including rice, feed grains including grain sorghums and soybeans, nuts, tobacco, peanuts and coffee. Farm processing studies are under way for forage wafering and hay storage; precooling of freshly harvested crops such as citrus, sweet corn and vegetables; pre- and poststorage treatment of potatoes; dehydration and mechanical dewatering of crops; seed and grain cleaning and separation; and trimming, peeling, and juicing operations for crop marketing.

Closely associated with these studies are development and adaptation studies of flow systems, equipment and packages to move products without damage into and out of storages and to the market place.

Much of this research is cooperative with the Department.

A total of 38.6 man-years effort is devoted to this work.

### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

#### A. Seed cleaning

1. Seed cleaning research applied to specific problem mixtures. At Corvallis, Oregon, 45 problem seed mixtures were processed through the laboratory, and reports were sent to the seed processors with recommendations as to the methods, machines, and type and size of screens to use in making the separations.

The scientific method of microscopically measuring seed was further explored to determine size and shape of screens, and the diameter and depth of indent pockets to use in making a separation by any dimensional difference. Some of the seed separation problems solved for farmers during the year using this method were as follows: Ryegrass from orchardgrass, yellow cress from bentgrass, bluegrass doubles from bluegrass. Seeds measured and data calculated during the report period included bluegrass, bentgrass, cottonseed, cocklebur, wheat, barley, corn, mustard, ryegrass, orchardgrass, alfalfa, and Russian pigweed.

The vibrator separator that separates materials by sensing their shape and surface texture continued to give satisfactory results. New separations made during the report period were: Zinnia seed from stems and cone particles, carrot seed from dodder seed, and onion seed from seed pods.

2. Development of centrifugal-pneumatic separator. The initial research on the centrifugal-pneumatic separator involved the passing of a seed mixture down the inside of a rotating screen and using pneumatic force in opposition to centrifugal force to accomplish separation. Centrifugal force on individual seeds varies as the square of the velocity in accordance with the formula  $F = \frac{MV^2}{gr}$ . Pneumatic force is provided by a flow of air from outside to inside the screen. Theoretically, precise separation should be possible by increasing the speed of the screen to a point where the differential between forces on a light and a slightly heavier seed would cause the lighter seed to be lifted. A new approach is to use the centrifugal force and the fanning action of the revolving screen to increase the accuracy and capacity of the screen. A commercial rotating-vertical screen used in separating materials in the mining industry has been made available to the project by the manufacturer to determine its feasibility for use in seed processing.

3. Modification of seed-length separator. At Corvallis, Oregon, seeds in problem mixtures are microscopically measured for length, width, and thickness, and the data used to determine the diameter and depth of the indent pockets required in the design of a special indent cylinder to make a specific seed separation. This method materially increases the use of length separators in processing seeds. Commercial manufacturers are presently making only nine sizes of indent pockets. Each diameter indent pocket has only one depth, which means that a mixture has to be adapted to the available indent cylinder. On the research project, a unique method is being used to construct indent cylinders with indent pockets of the theoretical size dictated by the dimensions of the seeds to make a specific length separation. Several farm seed processors have used this method in the construction of special indent cylinders to fit their standard machines. Measurement data and preliminary tests of seed mixtures (using the measurement data) indicate that special indent cylinders could be used commercially to separate wheat from barley, cocklebur from cottonseed, mouse-ear from bentgrass, and canary grass from white clover.

4. Development of vibratory feeders for use in studying seed cleaning and handling machinery. Previously developed off-center rotating-weight mechanical vibrators and pulsating-magnet electric vibrators continued to be used as feeders and vibrators for many seed separating, blending, and sampling units, both in the experimental laboratory and in commercial applications. No new developments were made on this project during the year.

## B. Tobacco curing

1. Certain thermal properties of tobacco during the cure. The object of this investigation has been to determine the thermal conductivity, specific heat, and thermal diffusivity of turgid tobacco during the cure. These basic "engineering" properties are needed in the analysis, design and development of facilities for controlling the environmental and curing processes of tobacco. The apparatus used was a guarded hot plate designed and constructed after ASTM specifications but with modifications to account for pertinent biological characteristics of test specimens. Each test specimen was formed from approximately 25 to 75 individual discs 4-1/2 inches in diameter cut from the leaf lamina and stacked to a thickness of approximately 1/2-to 5/8-inch when compressed within the apparatus during a test. Three apparent densities were tested: 30, 35, and 40 lbs./cu. ft. The thermal conductivity of the laminated specimens was found to be significantly influenced by both moisture content and apparent density. Specific heat was found to be significantly influenced by moisture content. Thermal diffusivity was determined from the developed data. It is recommended that the equations developed be used to predict values of diffusivity as a function of the influencing factors. By this method, diffusivity was found to be essentially constant with a value of approximately  $.0029 \text{ ft.}^2/\text{hr.}$  up to 50 percent moisture content (wet basis) regardless of apparent density. Above 50 percent, diffusivity increased rapidly and was also affected by different apparent densities.

Measuring the coloring rates of primed burley leaves with time-lapse photography. Basic information concerning tobacco responses to the curing environment was obtained under laboratory conditions. The colorating rate of leaves was measured by single-frame exposure of 16 mm color film at 1-hour intervals over periods from 4 to 12 days. Coloring rate was assumed to be directly related to curing rate for the samples tested. Tests were conducted at 80°, 90° and 100° F. with approximately the same leaf drying rate at each temperature (2 percent per hour dry weight basis). The leaf coloring rate increased significantly with temperature in the range 90° to 100° F., but not in the range 80° to 90° F. The time for complete leaf yellowing was about 300 hours at 80° F., 225 hours at 90° F., and 50 hours at 100° F. These results indicate the possibility of shortening the curing period by controlling the temperature at or near 100° F.

## C. Decorticating, retting, and cleaning long fiber crops

1. The research on improving processes and techniques for cleaning ramie ribbons has been cooperative with the Everglades Experiment Station which has conducted most of the degumming and fiber quality tests as well as adapting the local product to the manufacturers needs. The planting at the station has been fertilized and kept in good growing condition. One cutting was harvested with the USDA harvester-ribboner for yield determinations, and to supply material for cleaning, degumming, and other fiber tests. A

part of the harvest was washed through the squeeze-roller type washer. Considerable improvement was noted in color and gum content. The economics of washing is questionable since the field machine removed all foreign materials that could not be taken care of in the degumming process.

#### D. Grain drying

1. At Ames, Iowa, studies are underway for isolating the factors that enter into rational design of drying equipment and for developing quantitative descriptions of their relation to economic design. Six additional tests of drying rate with corn have been made, each test including 16 samples at various initial grain moistures and air velocities. Some of the samples were stored at low temperature before testing. The drying rate appears to be faster in corn after holding than it is immediately after harvest. Whether this increased rate can be utilized in practical drying operations is a question. Tests at various initial grain temperatures have been made without finding any significant effect of this factor. With the aid of the University computer, various models of response as related to temperature, moisture content, etc., have been tested, but so far none has been found to describe the drying rate better than the one developed from grain sorghum drying data.

2. Studies of the drying zone in mechanical driers were continued through use of laboratory model drying bins. The drying zone refers to that part of the grain in a drying bin in which drying is actually taking place at any time. The zone moves through but, in general, at any time during drying, part of the grain is drying, part is already dry and part is still at its initial moisture. The temperature and moisture gradients in the drying zone determine the efficiency and the required drying time in any drier. In order to define the relationships between the depth of drying zone and the factors of grain moisture, equilibrium moisture relationships, air flow rate, air temperature and humidity, laboratory apparatus and techniques capable of measurements of good accuracy are required. Air temperature control has been improved in the model drying bins so that drying air temperature can be maintained constant over long periods of time with less than  $0.1^{\circ}$  F. variation. An electric hygrometer was adapted to accurately measure humidity change of the air as it passes through the drying zone. The apparatus was proven with tests on rewetted shelled corn.

3. The time limitation on deep bed or in-storage grain drying systems is dictated by grain deterioration which is caused primarily by the growth of molds and bacteria. Of secondary importance may be the respiration or growth of the seed itself. The properties of grain which influence the rate of growth of the microflora are moisture, temperature, and the amount of physical damage of the grain. It is the purpose of this study to evaluate the influence of these factors on the rate of growth of the microflora and subsequently the rate of deterioration. One test run with freshly harvested wheat, one with freshly harvested corn and two with corn after storage at  $32^{\circ}$  F. were made. Each run included a full range of temperatures and moisture content. Hand-shelled

corn was used in this year's tests. The studies on mechanical damage were made by applying a more or less definable injury to each kernel rather than making up samples of severely damaged corn from field-shelled corn on which it is difficult to describe the damage. It was reported previously that field-shelled corn respired 2 to 3 times as fast as hand-shelled corn at the same temperature and moisture. Examination of the samples after these treatments showed that there is an even wider difference in mold deterioration than there is in respiration. A hand-shelled sample may be held 4 to 5 times as long as a field-shelled sample at the same conditions before it exhibits a similar degree of visible mold damage. Wheat respiration responds to differences in temperature and moisture in a manner similar to that of corn. Holding corn at cold storage temperatures prior to measuring the rate of deterioration increases the rate at which it will respire when exposed to higher temperature. This information will have application in the high moisture corn storage process.

#### E. Forage Processing

1. Pelleting studies on baled, sun-cured Coastal bermudagrass show that the production rate is only about 56 percent of that of dehydrated hay. The grinding and pelleting energy is about 38 percent greater than for dehydrated hay. When the hay was chopped and run through the dehydrator with a 100° temperature rise, the grinding and pelleting energy was reduced but the overall energy expense was increased from \$2.45 to \$4.90 per ton of dry matter. This study will be continued by using sun-cured hay directly from the field.

Comparisons of the energy for processing alfalfa and Coastal bermudagrass showed that more energy was required to dehydrate and grind alfalfa than Coastal bermudagrass, but Coastal bermudagrass required more energy for pelleting and regrinding (grinding the pellets). The total energy requirements, in kilowatt-hour (kw.-hr.) equivalent, per ton of dry matter produced were 3,829 kw.-hr. for alfalfa and 2,779 kw.-hr. for Coastal bermudagrass on the basis of local prices, the energy costs per ton were \$9.61 for alfalfa and \$7.60 for Coastal bermudagrass.

Systems of utilization of Coastal bermudagrass showed, for the second year, that dehydrating and pelleting produced more pounds of beef per acre than any other system tested. Dehydrated and pelleted Coastal bermudagrass produced 702 pounds of beef per acre compared to 582 pounds for dehydrated hay, 530 pounds for continuous grazing, 410 pounds for strip grazing, 389 pounds for rotational grazing, and 366 pounds for green chop feeding. The calculated gains, assuming complete utilization of all forage, are 895 pounds for pellets, 840 pounds for dehydrated hay, 530 pounds for continuous grazing, 505 pounds for rotational grazing, 425 pounds for strip grazing, and 787 pounds for green chop feeding. The total processing energy cost was \$34.63 per acre for dehydrating and pelleting and \$25.99 per acre for dehydrating only. On the basis of calculated gain, these produced respectively 365 and 310 pounds more beef per acre than continuous grazing.

2. Investigations of the expanding of alfalfa hay showed that neither fresh forage nor dehydrated alfalfa meal could be expanded with a dog food expander. However, fresh alfalfa forage processed with an oil expeller tended to separate free moisture and cell contents into one fraction and cell wall constituents into another fraction.

#### F. Tung nut processing

1. Farm processing of tung nuts. Conditioning high moisture tung fruit with or without hull for quality maintenance during storage requires knowledge of the basic factors and parameters affecting release of moisture from tung fruit. Additional data on the relation of static pressure to air flow rate, depth and density of fruit, were obtained. The static pressure requirements were much lower for equivalent air flow rates of tung having the lower moisture content. Additional studies will be made to determine the drying requirements of tung with and without heat. The information already obtained relating static pressure to air flow will be used as a guide for further studies.

#### G. Drying castor seed

1. Resistance of hulled and unhulled castor beans to air flow. Castor beans, at times, are harvested with high moisture content not acceptable to the processor. In addition, castor beans stored at high moisture are subject to deterioration and increased acid content of the oil within the seed. Investigations were continued to determine the relationship of air flow to resistance, density, moisture and depth both for hulled and unhulled castor beans. A pilot dryer was remodelled to allow more accurate air flow and resistance measurements than permitted previously. Basic relations of these factors are yet to be analyzed by multiple regression. Exponential equations and correlation coefficients will be determined. Results of these data will be used as guidelines for drying studies of hulled as well as unhulled castor beans.

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## AREA 6 : COTTON GINNING

Problem. This area is specifically concerned with the separation of the cotton lint from the cottonseed and those associated processes that pertain to cleaning, drying, handling of lint, seed and trash, packaging, and sampling to preserve the inherent qualities of the end products. This is the final operation in the process of cotton production since, subsequent to ginning, title to the lint and seed passes from the producer and the products enter the market channels.

Advances in cultural practices in the mechanization of cotton harvesting will depend to a great extent on continued research to develop adequate ginning equipment, improvements in present equipment, and improved practices in using equipment. The solution to many of the difficult problems of modifying the gin to meet the needs of mechanically harvested cotton are still ahead.

Cotton ginning problems are greatly influenced by the increase in rapid harvesting methods on one hand and the increased production rates in manufacturing, on the other. Modern methods in harvesting and manufacturing in the interest of reducing costs place more stress on the cotton fiber than ever before and more of a burden on the gin in coping with increased amounts of foreign matter and preserving the inherent quality of the fiber while preparing it for mill use. Among the more pressing problems are those growing out of modern methods of harvesting and handling cotton. They include means for reducing the power and labor requirements for gins and methods for dealing with air pollution and trash disposal as a result of handling large quantities of foreign matter. A method for evaluating seed cotton is also needed to serve as a measure of quality inputs to the gin for research purposes.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, materials handling engineers, and systems engineers engaged in both basic and applied research on the engineering phases of cotton ginning and handling. Seed cotton handling and storage research is currently being conducted at Stoneville, Mississippi. Research on seed cotton drying and seed cotton cleaning is being conducted at Clemson, South Carolina, and Stoneville. Conveying equipment and gin stand studies are carried on at Mesilla Park, New Mexico, and Stoneville. Research on gin performance and cotton quality is conducted at Stoneville, Clemson, and Mesilla Park. Lint cleaning studies are conducted at Stoneville and Clemson. Research on cottonseed handling is carried out at Stoneville, and waste collection and disposal studies are conducted at Stoneville and Mesilla Park. Research is cooperative with state experiment stations, Agricultural Marketing Service, Economic Research Service, industry, and individuals, as well as other Divisions in the Agricultural Research Service.

The Federal engineering effort devoted to research in this area totals 17.5 professional man-years. Of this number, 0.3 is devoted to seed cotton handling and storage, 1.9 to seed cotton drying equipment, 3.2 to seed cotton cleaning, 0.4 to conveying equipment, 2.1 to gin stand, 6.0 to gin performance and cotton quality, 0.5 to lint cleaning, 0.3 to packaging, 0.2 to sampling, 0.2 to cottonseed handling, and 1.9 to gin waste collection and disposal, and 0.5 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is conducted in only two State agricultural experiment stations; namely, Oklahoma and South Carolina. The Department has been specifically concerned in this area for several years and has carried on the major program of research on the engineering phases of premarket cotton processing and handling.

The Oklahoma research involves the adaptation and testing of cotton ginning equipment, techniques and related operations for reducing the cost and delay in handling and conveying seed cotton on the gin yard and in the gin. In addition, evaluations are being made of the quality reductions associated with green and immature bolls in harvested cotton as well as determination of the effects that various combinations of cleaning, drying, and ginning machines have on returns to the producer.

The South Carolina studies are concerned with the development of new principles and techniques for ginning cottons. Characteristics and properties of seed cotton, lint, and seed related to the basic ginning processes are being investigated as well as the effects that various physical actions have on fiber and seed.

A total of 3.3 man-years are devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Seed cotton handling and storage

1. Some preliminary investigations were made at Stoneville in cooperation with the Cotton Harvesting Investigations of the types of trailers used in the sugarcane harvest. These trailers may be unloaded mechanically, thus effecting a labor savings. The principle involved appears to have some promise and will be investigated further for possible adaptation and use in handling seed cotton.

##### B. Seed cotton drying

1. Any material which will change the electrical resistance of cotton will affect the accuracy of the automatic drier control system of the gin. Tests were made at Stoneville to determine if the commonly used insecticides and defoliants caused a specific effect on the electrical resistance of

cotton fibers en masse. The commonly used insecticides and defoliants studied in 16 separate experiments showed that normal use of these chemicals does not require special calibration of gin drying systems based on fiber electrical resistance measurement. However, variations in density will affect fiber resistances sufficiently that gin drying systems using the resistance measuring principle should be calibrated at and for some specific fiber mass density. Also, provisions should be made to maintain that density for proper system operation. The relationship between density and resistance was found to be logarithmic.

At Stoneville studies using an experimental zero-gradient drier to determine the effect of initial fiber moisture level before drying, air to seed cotton mass ratio, temperature, and exposure time upon quantity of moisture removed were conducted. Results showed the quantity of moisture removed to be directly proportional to initial moisture content. The factors, temperature and exposure, showed a logarithmic relationship to final moisture content of fiber under conditions of the experiment. Changes in air to seed cotton mass ratio caused small changes in fiber moisture content when compared to the effect of temperature and exposure.

Tests at Clemson using six moisture levels of drying showed that cotton ginned at a lint moisture content in the 8.0 percent range will preserve the use value of the cotton and yield satisfactory bale values for the producer when current ginning machinery recommendations are followed. When lint cleaning was used, cotton could be ginned at 8.5 percent lint moisture content without encountering rough preparation.

### C. Seed cotton cleaning

1. Comparative tests at Stoneville showed that the micro-gin gave results comparable to a full-size gin at the laboratory. These tests confirm the theory that this small plant can replace full-size equipment in many instances as a research tool.

A serpentine cleaner developed at Stoneville was tested in the full-size gin. The tests show that the serpentine cleaner, which has no moving parts, is just as efficient as a conventional cleaner of the same open grid area.

Studies of the sequence of seed cotton cleaning machinery at Stoneville show that where a single unit 7- or 13-cylinder cleaner is used in conjunction with a stick and green leaf machine best cleaning is obtained when the stick machine precedes the cylinder cleaner. When two separate 7-cylinder cleaners were used with one immediately preceding the stick remover and one following, grade and cleaning results were essentially the same as when the unit stick remover was arranged to precede the 13-cylinder cleaner. With this fact in mind, it is believed best to have the cylinder cleaning divided into two units so that one 6- or 7-cylinder cleaner would precede and one follow the stick removal equipment. According to the experiments, this would not provide any better grade and cleaning, but would serve to better prepare the

cotton for passage through the stick remover by dispersing any wads for better feeding and less cotton loss during its passage through the stick removal equipment.

Spinning and fiber data did not show any consistent trend of important differences in fiber and spinning test results between 18 different overhead machinery arrangements tested.

Tests at Stoneville on a special strain of cotton bred for stripping in Arkansas showed that the normal machinery arrangement recommended for machine-picked cotton gave satisfactory results. The cotton was rather coarse, 5.7 micronaire, and 12 experimental ginning treatments all gave grades of Strict Low Middling. Stripping tests on a commercial rain-grown variety gave grades equivalent to machine-picked cotton for early season stripping. However, cotton stripped late in the season contained such a preponderance of large tough foreign matter that it was not practical to gin it. The experiments with stripping this commercial cotton demonstrated that the cottons which have been bred for spindle picking in the Mid-South area are not at all suited for stripper harvesting from a ginning standpoint.

A screw conveyor cleaner was modified and subjected to a second year of tests at Clemson. The cleaning grids under the conveyor which gave the greatest trash removal also gave the greatest cotton loss with the trash. The installation of a "breaker cylinder" immediately below the feed rollers in the feed control tended to single lock the cotton thus exposing more foreign matter and increasing the cleaning efficiency of the device. The cleaner had no effect on Shirley Analyzer or Colorimeter results. Classer's grade index and price per pound of lint, after reductions due to grass, for cottons subjected to the grids at one-half inch clearance from the conveyor were significantly greater than that of all other treatments. Measurable fiber properties were not affected by the screw conveyor cleaner regardless of cleaning plate design. Marked decreases in upper half mean length, strength and micronaire reading and a pronounced increase in short fiber content were noted in fiber samples from seed cotton removed with the trash by all cleaning plates tested.

It is an accepted fact that trash is removed more easily from seed cotton which has been separated into individual locks. A device designed to separate the locks of cotton was constructed at Clemson for tests. The device appeared to perform satisfactorily but the anticipated increase in cleaning efficiency did not materialize.

2. Evaluation tests were made at Clemson on an experimental drum-type tight lock separator and an auger-type separator, using seed cotton which averaged 3.48 percent of tight locks by weight. By removing the tight locks from the cotton the average bale value was increased \$4.01 when using the drum-type separator and \$1.89 with the auger-type.

#### D. Conveying

1. Tests at Stoneville using three vane-axial fans showed that, when vane-axial fans are operated in series, the static pressure delivered is slightly greater than the sum of the individual static pressures and the horsepower is slightly less than the sum of the individual horsepowers. The volume and static efficiency shows a slight overall increase with each additional fan stage. Series vane-axial fans are more efficient than comparable centrifugal fans.

Investigations of various materials handling techniques at Mesilla Park has yielded a principle of conveyance that appears to be more economical than conventional methods, and it is believed to be applicable to several materials handling situations in cotton gins. The principle involves the use of a number of low-pressure air-jets to lift and push the material along on a cushion of air. Preliminary trials conducted by the manufacturer of the conveyor showed that seed cotton, lint, gin trash, and cottonseed could all be conveyed using this principle. A pilot model of such a conveyor has been constructed and testing has begun. Initial results look very encouraging. Arrangements have been made to obtain a full-scale unit for further investigations this coming year.

#### E. Gin stands

1. Saw gins. Studies at Stoneville showed that the huller front of a high-capacity gin was an inefficient cleaner and it is doubtful that it is of sufficient value to warrant its continued use with machine-picked cotton.

Studies of the effect of high-capacity gin stands on cottonseed quality indicate that the germination is lowered slightly as a result of the mechanical damage incurred during the process of removing fibers from the seed.

Investigations were made to determine the feasibility of using reconditioned high-capacity, large-diameter gin saws. Saw diameters were reduced by one-sixteenth inch by repunching the saw teeth. The tests showed a slight reduction in ginning capacity, and an increase in power and energy requirements for the reduced diameter saws.

2. Roller gins. An electro-mechanical gage developed at Mesilla Park facilitates rapid accurate setting of the overlap of the moving knife to the stationary knife on reciprocating roller gins. This is the first time that any gage or device has been devised to aid the ginner in properly adjusting his equipment.

Research to date at Mesilla Park has not yielded a satisfactory means for keeping the roll surface and stationary knife cool on a high-capacity roller gin during ginning. However, it has been found that maintaining an even feed of cotton to the machine will reduce the temperature 50° to 100° F. This will prolong the life of the roller and thereby reduce maintenance and

down-time. The tests also showed that the use of humid air in the conventional doffing system of a modern rotary-knife roller gin would serve to control static.

#### F. Gin performance and cotton quality

1. Data were collected on effective gin operating time by the Stoneville Laboratory from seven commercial gins in the Mid-South area during the 1963 ginning season. Efficiencies of operating time for these gins ranged from 74.3 to 91.0 percent, with an average for the seven plants of 86.9 percent. Four of the plants studied displayed operating efficiencies of 90.0 percent or higher. Plant operating efficiencies of 90 percent cannot be obtained without excellent plant management and a gin crew in which each member pays close attention to every detail involved in his specific job. Studies were also made to determine the power and energy requirements for operating presses and trampers in cotton gins. Average energy consumption for the presses studied was 0.29 kw.-hr. per bale, with an average power requirement of 10.7 horsepower. The trampers studied used an average of 0.18 kw.-hr. per bale, with the average power requirement being 2.6 horsepower.

The engineering data collected on saw and roller gins by the Mesilla Park Laboratory shows that high-capacity gins generally have from 35 to 50 individual drive motors. The study further showed that the gins had a much higher connected load than that required to operate. This over-powering of equipment contributes to lower power efficiency and high operating cost. The ginners' power costs are higher than they should be for three reasons: (1) High installation cost because of the larger motors, wiring and control equipment; (2) under-loaded induction-type electric motors have a low power factor characteristic which results in higher current requirements than necessary, and in some instances power cost penalties are levied on low power factor demand loads; and (3) the ginner is paying for connected loads not needed for operation.

Effective operating time of gins in the Southeast was affected by the methods used for bringing cotton to the gin. Much of the cotton is delivered in one-bale lots and some in burlap sheets which are awkward and time-consuming to handle. Both practices contribute to increased total power costs because of the numerous delays. Generally speaking, the larger the lots the more efficient the operation. The Clemson Laboratory found that 51.1 to 56.6 kw. per bale was required for ginning.

2. Quality evaluation. Refinements of the seed cotton foreign matter determination test were made at Stoneville. It was found that for seed cotton cleaning and other tests where an analysis of the various types of foreign matter is important as well as the total quantity, a procedure which involves the use of three trash screens in lieu of the original two is recommended. The screens are of different size, thus the various sizes of leaf trash are separated.

Refinements were made at Stoneville of the Shirley Analyzer test procedure to give more information on the trash in lint cotton. It was found that when a 1/4-inch mesh screen was placed 1-1/8 inches from the bottom of the trash pan, the larger foreign matter particles collected on it, thus giving a separation of "large" and "small" trash in the lint. This is especially helpful in lint cleaner studies.

Formulae developed at Stoneville for calculating the moisture content of the seed cotton after 2 hours of oven drying proved to be satisfactory. There was less variation between this procedure and paired samples dried in the conventional manner.

In cooperative tests with the Crops Research Division studies were made at Stoneville of the fiber-seed separation force for four cottons (two Sp. G. Barbadosense and two Sp. G. Tomentosum). It was found that Pima S-2 separated from its seeds with less force than did Pima S-1. Pima S-2 also had fewer fibers to rupture than S-1 during fiber-seed separation. The Tomentosum fiber rupture rate was greater than that for the Pimas.

Single fiber tests were made at Stoneville at weekly intervals on fiber-seed separation force and tensile strength--8,890 separate tests were made. Both tensile strength and separation force declined as field exposure increased; tensile strength declined faster than fiber-seed separation force. The percentage of fibers that ruptured instead of separating normally from the seed increased as exposure period increased. These data indicate that the ginning process will break more fibers from late-harvested cotton than from cotton harvested shortly after opening.

Studies at Mesilla Park show that the amount of moisture absorbed by various strains, species, and varieties of cotton under given conditions is not significantly different. Studies also show that alkali-centrifuge values are not affected by ginning methods but are affected by time of harvest.

At Clemson, the Shirley Analyzer was used in an effort to magnify differences in fiber properties which were caused by ginning treatments. One pass through the Shirley Analyzer did appear to increase the differences with no advantage being found for additional passes through the machine. Correlation coefficients did not increase for five passes as compared with one pass through the machine when yarn strength was correlated with fiber tensile strength and percent fibers shorter than one-half inch.

3. Effect of cultural and harvesting practices. Work at Stoneville on four varieties of cotton showed that stripping was not practical. Hand-picked lots were used as a control. All of the hand-picked cotton was classed as Middling, 1-1/32 inches. The average grade of the stripped cotton ranged from a high of 96.4 for Stripper 60-2 variety downward to 92.8 for Lankhart-57; 91.3 for Stoneville 7-A, and 89.7 for Rex Smooth Leaf. Until higher-yielding stripper cotton that will mature early and

maintain its quality can be developed, it is believed that picker harvesting will continue to dominate in the Delta area. On the sandy loam soils the present cottons cannot be produced with a stalk small enough for stripper harvesting.

Tests at Stoneville using three types of picker spindles with a hand-picked control showed that there was no important difference in the grade and staple length of the samples representing the three different spindles. The average grade of the mechanically-harvested cotton was SLM, and the hand-picked averaged Middling. The staple length of both the machine- and hand-picked was 36.1 in one-thirty second inches. A statistical analysis of the fiber and spinning data shows no significant differences in the machine- or hand-picked cotton with respect to neps, ends down, yarn appearance, fiber array length, fibers shorter than one-half inch, fibrograph length, fiber strength, or Uster strength (single strand) and imperfections. As is normal, there was a significantly lower picker and card waste associated with the hand-picked cotton. Although the statistical analysis shows significance at the 5 percent level for yarn break factor, picker and card waste and micronaire readings, all treatments fall within a close range which would not be important from a spinning mill processing standpoint.

A study of the same organization carried out by the Mesilla Park Laboratory showed only slight differences between treatments except for a significant difference in corrected spinning ends down per thousand spindle hours in favor of hand picking.

Experiments were carried out at Stoneville to determine the degree of cotton contamination by picker spindle grease and its effect on cotton quality. Lots which were harvested immediately after servicing the picker averaged 0.55 percent grease content whereas lots harvested after 3 hours contained only 0.3 percent. Generally speaking the picker and card waste was directly proportional to the grease content while the color and yarn appearance were inversely proportional.

For the second year tests were made at Stoneville on the effect of a layby chemical for late season grass control. The machine-picked wagon sample grass content of the treated field was zero as compared to 0.2 percent for the grassy field. The results of the experiments indicate that the grass encountered when not using the layby treatment (control field) has no adverse effect on harvesting efficiency or time required to harvest. When double lint cleaning is used at the gin, the grass removal from the control lots was complete enough to have no effect on the grade of the cotton. The fiber quality was the same for all treatments.

Studies of gleaning operations at Stoneville show that the net return to the farmer from gleaning operations was \$87.07 per bale with six acres of gleaning required to make a bale. As compared to conventional picker spindle scrapped cotton, the gleaned material was lower in quality.

A study carried out at Stoneville showed that the range in foreign matter content in a picker basket was not significant. The tests showed that the equalizing effects of processing the cotton through the cleaning system of the gin gave the same average foreign matter distribution in the cotton at the gin stand. This resulted in essentially the same lint grades and closely comparable lint foreign matter content throughout the bale.

Tests of ginning performance and quality of two varieties in the 1961 crop and four varieties in the 1962 crop which were ginned under varying conditions at Mesilla Park were analyzed together. The data showed that Acala 1517BR-2 ginned faster than 4-42, A44, and western grown Deltapine. The BR-2 had the longest fibers by classer and laboratory measurements, and relatively small seeds with low linters percentage. All varieties, ginned at 30, 50, and 70 percent relative humidity, showed that the higher humidities are significantly better for ginning capacity and fiber length and produced fewer short fibers. Tenacity measurements had very little effect on ginning capacity among varieties, and the average tenacity for all varieties was not effected by relative humidity.

Groups of strains from three western cotton breeders were also tested. New Mexico State University included 1517D, BR-2, 6368, 8229, and 6612, the last of which was released this year as 1517V, a strain tolerant to Verticillium wilt. The 6612 had slightly better ginning capacity and turnout than did most other strains; it was bested only by the experimental strain 8229 in these two measurements. Of the Shafter, California, strains, AR-42-77, had the highest ginning capacity and turnout and of the American-Egyptian strains, Pima S-2 with smaller seeds, led S-1 and two experimental strains in capacity and turnout.

#### G. Lint cleaning

1. A study was made at Stoneville of the effect of lint moisture content on trash removal and on fiber length distribution of cleaned lint. Test results showed some additional trash removal due to lint cleaning at lower moisture levels, but a more substantial quantity of trash was removed by employing a second lint cleaner at the same fiber moisture content. Upper half mean and mean length data showed some decreases in fiber length when cleaning lint at low moisture contents. However, these changes were due partially to gin stand effect.

Tests at Clemson showed that one lint cleaner would not give sufficient cleaning to prevent grade reductions because of grass. In machine-picked cotton containing a preponderance of grass, 73.3 percent of the samples were reduced one grade because of grass, 22.2 percent had a trace of grass but were not reduced, and only 2.5 percent were classed as free of grass.

## H. Cottonseed handling

1. Studies of the effect of conventional gin seed handling systems conducted at Stoneville indicated that excessive handling of cottonseed will (1) lower seed germination, (2) increase physical damage to the seed coat, and (3) increase the percentage of abnormal seed. These studies will be expanded.

## I. Waste collection and disposal

1. Research at Mesilla Park has led to the development of an efficient means of collecting fly lint and dust escaping from low-pressure, high-volume condenser exhaust systems in cotton gins. During Fiscal Year 1964 a pilot model inline air filter for condenser exhaust systems was designed, built, and tested at the laboratory. The filter was equipped with stainless steel bolting-grade wire cloth as the filtering media. Tests have shown this type of media to offer only small restrictions to the flow of air while maintaining high filtering efficiencies. The pilot model inline air filter performed sufficiently well in the laboratory to warrant the construction of two larger units which were field tested in a commercial gin on individual lint cleaner condenser exhausts during the 1963-64 ginning season. The field test results showed that the inline air filters could be easily installed in any system and were an efficient, economical, and trouble-free means of collecting condenser exhaust air pollutants. These test units were 99+ percent efficient in collecting fly lint and foreign matter particles larger than 165 microns and 70 percent efficient in collecting fine dust particles less than 165 microns. This produced an overall efficiency of 87 percent. These field tests, along with other laboratory tests, also enabled the formulation of concrete design procedures to assist ginners and manufacturers in the design of inline filters to meet the various conditions encountered in commercial ginning operations.

Measurements made at Stoneville show that the dust concentration inside a modern cotton gin is about the same as that of industrial districts, and the noise level is well below the level which will cause pain.

Preliminary tests at Stoneville indicate that lint fly from the exhaust of low-pressure condenser fans may be greatly reduced or eliminated by covering the condenser drum of the lint cleaner or battery condenser with a fine mesh screen wire cloth.

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## AREA NO. 7. STRUCTURES FOR CROP AND MACHINERY STORAGE AND PLANT GROWTH

Problem. Vast quantities of crops and other materials are handled and stored on the farm. Annually: (1) Five billion bushels of corn, wheat, and other grains are harvested and stored, of which nearly 1 billion is carried over from the preceding year; (2) 185 million tons of hay and silage are processed and stored; (3) nearly 3 million bushels of apples and pears and 13.5 million hundred-weight of potatoes and sweet potatoes are held for home consumption; (4) other large quantities of fruits and vegetables are held for temporary storage pending marketing; and (5) large amounts of fertilizers and feeds are purchased and held in storage pending use. Many of the more than 7 million tractors, combines, corn pickers, and other complicated farm machines would retain their efficiency longer and operate more reliably if stored under shelter and tuned up in farm shops.

Relatively little research on farm storage structures has been done in recent years--even though there have been many new developments that affect storage and handling problems. For example, the trends toward large diameter silos and different silages call for new data on pressures exerted against the silo structure.

There is also urgent need to develop engineering design criteria for constructing and equipping plant growth chambers that will reliably provide and maintain desired thermal, lighting, and other environments over a wide range of experimental conditions. Recent experience of plant and other scientists concerned with use of plant growth chambers indicates a general inability to closely maintain desired environmental conditions and a lack of means for measuring conditions maintained in these units. Design criteria for automatically maintaining scheduled environments are needed also for greenhouses and other production type plant growth structures.

### USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans for storage and plant growth structures.

A. Crop Storage Structures (silos and bins). Research is cooperative with Animal Husbandry Research Division, ARS; with Cooperative Regional Research Project NE-13, "Determination of the Basic Job Requirement of Machinery for Harvesting and Storage of Grass Silage", at Beltsville, Maryland; and with the Agricultural Experiment Stations at Athens, Georgia; East Lansing, Michigan; Davis, California; and Ames, Iowa.

B. Plant Growth Structures (environmental chambers and greenhouses). Research at Beltsville, Maryland, is cooperative with Crops Research Division, ARS.

C. Plan Development. Typical plans for crop structures and related equipment are developed at Beltsville in cooperation with the regional committees representing all State Experiment Stations and Extension Services.

The Federal effort in this research area totals 4.0 professional man-years. Of this number 2.6 are devoted to crop storage structures; 1.0 to plant growth structures; 0.1 to plan development; and 0.3 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The complicated problems associated with providing protection to the products of agricultural production as well as the machines, equipment and service facilities which are required for such production has necessitated a continuing program of research at the State Agricultural Experiment Stations.

The current broad scale program is concerned with conditioning and storages for high moisture grains; curing, bulk handling and storage for onions; curing and storage sheds for tobacco; structural characteristics, wall pressures, design and construction of silos; Irish potato and sweet potato plant production facilities and storages; controlled atmosphere storages and construction methods; designs for machinery sheds and farm service buildings; and designs and construction of plant growth chambers and plastic greenhouses.

Much of this research activity is cooperative with the Department.

A total of 10.5 man-years is devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Crop storage structures

1. Silo design criteria. Determination of forage density in normal storage conditions, using a radioisotope, continued at Beltsville, Maryland. Formation of a denser column under a plain loading pipe was investigated with wilted alfalfa. Although of irregular shape and not sharply defined, a dense region did occur and no doubt prevented settling of other silage. However, within the range of density, 15-29 lb./cu. ft., there was no apparent effect on occurrence of small moldy regions. Heating of silage near the surface during unloading occurred mostly on the border of the denser region. The tramping which occurred during hand leveling formed a layer 30 percent denser than underlying silage. No measurable re-expansion occurred during unloading of this top unloading silo. Wilted alfalfa will be further studied with emphasis on packing effects of chop length and dryness.

At Athens, Georgia, research continued on measurement of the gaseous transfer rate of silo construction materials. Rates of oxygen flow through concrete with partial pressure differences across the specimens are now being determined. Various treatments such as paint, epoxy and plaster are being used on the concrete. Small silos were made from 24-inch concrete pipe and filled with grain sorghum. Immediately after filling was completed, oxygen concentration dropped to nil, followed in 24 hours by a peak in CO<sub>2</sub> concentration of approximately 50 percent. Carbon dioxide concentration drifted back to a level of 20 percent after which the concentration seemed to level off. Oxygen concentration remained below 5 percent during the month of measurement except in areas of poor sealing around the cover. Sufficient results have not yet been obtained for valid comparisons of the treatments.

At East Lansing, Michigan, studies of corn silage pressures in large tower silos were continued. A 20- by 60-foot and a 30- by 60-foot silo were loaded with chopped whole corn, as in previous years, but the crop was so dry that no juice appeared with 60-foot depth and wall pressures were low compared to those of wetter corn. In the 30-foot diameter silo, pressure was roughly constant at 300 lb./sq. ft. up to 30-foot height, with maximum of 385 lb./sq. ft. at 25 feet; previously, maximums occurred below 10 feet and were substantially greater than pressures at greater heights. In the 20-foot diameter silo, maximum was 260 lb./sq. ft. at 2.5 feet, and pressures at all heights were less than in previous years. No pressures yet measured in this study exceeded silo hooping standards extrapolated from USDA data for smaller silos. Plans are to continue yearly measurements on two instrumented silos, and if possible, add other silos.

2. Heavily wilted silage storage. At Beltsville, Maryland, alfalfa was ensiled in 10- by 35-foot silos at 40, 52, and 58 percent dry matter and gave recovery of 90, 85, and 78 percent, respectively, from full size silos. The large loss in the driest silage, thought to be due to air leakage through cracks in the silo, occurred despite a surcharge of wetter silage and a shorter loading period than the other silages. Also, digestibility of the driest silage was lower. Although higher recovery rates have been recorded for heavily wilted forages, dryness greater than 50 percent at present introduces risk of large storage losses in conventional silos. This work will continue as needs are determined by cooperator consensus.

3. Bunker silo pressures. At Beltsville, Maryland, studies on wall pressures in a bunker silo continued to show a pattern of variation, but within normal design recommendations. In a bunker 8 feet deep, chopped whole corn gave sustained horizontal wall force of 300 lb./ft. of length, only half the value for similar conditions the previous year. This wood-walled bunker is still in good condition after 10 years. Plan is to continue pressure work only when forage of unusual characteristics is loaded.

4. Coastal Bermuda grass silage. Work at Athens, Georgia, on a basic study of factors influencing the storage quality of Coastal Bermuda grass silage was continued, but at reduced rate. Observations of conditions in 588 one-half gallon glass jars of this silage were continued but data have not been analyzed.

5. Hay wafer storage. At Beltsville, Maryland, a storage-drying-self-feeding structure was loaded with alfalfa wafers. Considerable fines were produced in loading by elevator and chute. A region including about a fourth of the bin plan area under the chute was saturated with fines and forced air flow there was only about a third of that through regions of whole wafers. The entire mass was satisfactorily dried, mold free and retaining good color, by heated air. Feeding gates, modified by addition of manger boards, greatly reduced waste compared to the previous year. Bridging of the wafer mass was a definite problem and required operator attendance daily, though little labor was used. No future work is presently planned.

6. High moisture shelled corn storage. At Ames, Iowa, studies on storage of high moisture shelled corn in eight 200-bushel airtight tanks were continued. Four tanks were located outdoors; one loaded with corn at 18 percent moisture, one at 25 percent, and the other two at 28 percent. One of the 28 percent tanks was ventilated at the rate of 100 cubic feet of air per day, 5 days per week, for the duration of the storage period--October 1, 1963 to March 1, 1964. The other three tanks were ventilated at the rate of 50 cubic feet per day over the same period. The same test conditions and treatments were applied to 4 tanks located inside a heated building. There was very little damage evident at the time of unloading. Feeding trials with poultry, made to compare the best appearing corn with the poorest at time of unloading, indicated no difference in rate of gain between chicks fed on different lots of corn, although some decrease in pounds of gain per pound of corn was observed for the poorest corn. This poorest corn had a test weight of only about 48 pounds per bushel, as compared to about 58 for the best.

## B. Plant growth structures

1. Environmental chambers. At Beltsville, Maryland, studies to develop improved design criteria for environmental chambers were continued.

A far-red light source, developed in 1962, was improved by: (1) Using a closer lamp spacing to raise the intensity and provide more uniform radiation; (2) using a clear plexiglas filter below the lamps, with forced ventilation to keep its temperature below 140° F.; (3) using a voltage regulator to maintain lamp voltage at slightly below the rated voltage to extend lamp life without materially changing far-red output; and (4) adding a relay to control the lamp on-off time with a remote time clock. The improved design has functioned perfectly during periods of continuous operation up to 72 hours duration.

A commercial angle transducer was adapted to measure plant growth, leaf movement, lateral stem movement, or other plant movements. Tests with bean plants showed the stalk has a 90-minute cycle side twisting movement and the leaf has various movement cycles. Tests were also run on growth of zinnia seedlings with various light treatments. Indications are that growth rate is greater during the dark and that there is a pause, or even a shrinkage, when lights are turned on. Many applications can be foreseen for this as a rapid means of detecting plant response to various treatments.

Tests with cocklebur plants in a refrigerated room showed that the plants remained healthy in air temperatures down to 15° F. when kept warm with heating cables and infra-red lamps.

Experiments to determine the effects of different lamps on growth of pinto (bush) bean plants continued. Emphasis was on determining the best incandescent-fluorescent lamp ratio. It was found that the incandescent light definitely has an effect on growth, and that the effect is complicated by other conditions such as ambient temperature, heating effect of incandescent light, time after planting and duration of incandescent light. For example, the data indicate the red-far red ratio is most important between the 12th and 16th days after planting.

2. Greenhouses. No reportable progress was made in research on greenhouses.

### C. Plan development

Two typical plans for dual-purpose fallout shelter-storage structures and one for a bagged fertilizer storage shed were developed during the year at Beltsville, Maryland, for inclusion in the Cooperative Farm Building Plan Exchange. The dual-purpose structures are (1) an underground, concrete, family-size fallout shelter that serves also as a fruit and vegetable storage and (2) a conventional on-farm potato storage with a family-size shelter in the center bin. When the bins are loaded in the latter, the protection factor is significantly increased. (The man-years for the dual purpose structures are reported under Fallout Protection, 10 F).

## PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

### Crop Storage Studies

James, P. E. and Wilkins, D. E. 1963. Silage density by gamma energy attenuation. Proceedings of Oak Ridge Radioisotope Conference, Gatlinburg, Tennessee. April 1-3, 1963. pp. 106-113.

### Plant Growth Structures

Agricultural Engineering Research Division. 1964. A plastic-covered greenhouse. (Exchange Plan No. 5946). Miscellaneous Publication No. 957. March.

Newman, Jerry O. 1963. A portable plastic greenhouse. Proceedings of the National Agricultural Plastics Conference, October 15-18, 1963. pp. 5-7.

### Plan Development

Agricultural Engineering Research Division. 1963. Farm garages. (Exchange Plan No. 5929 and No. 5930). Miscellaneous Publication No. 928. June

Agricultural Engineering Research Division. 1963. Storage, storm and fallout shelter. (Exchange Plan No. 5948). Miscellaneous Publication No. 950. December.

Agricultural Engineering Research Division. 1964. Fallout shelter in a farm potato storage. (Exchange Plan No. 5951). Miscellaneous Publication No. 949. January.

## AREA NO. 8. RURAL DWELLINGS

Problem. The 1960 Census of Housing indicates that although about 500,000 new farmhouses were built between 1950 and 1960, rural housing as a whole continues to be older than and inferior to urban housing in condition and value of buildings and in availability of plumbing, heating, and labor-saving equipment. Large numbers of houses outside of cities and towns remain without the conveniences and comfort features of typical urban homes.

Housing costs are still a major obstacle for farm families that wish to make improvements for themselves or to furnish better housing to attract and hold qualified and reliable tenants or workers, either full-time or seasonal. Costs are also a problem for the rural non-farm family. Continuing research is needed on ways to reduce costs through better use of space and improved application of old and new materials and use of more efficient construction methods. The stepped-up Farmers Home Administration program of rural housing loans needs research support to provide designs that will meet modern housing standards at moderate cost and be sound and desirable security for 30-year government loans. Further research is also needed on design and equipment of houses for improved control of temperature, air movement and noise, and economy of operation and maintenance.

With the rapid increase of the non-farm population in rural areas outside of villages, including many elderly and retired people, more attention should be given to their housing. People who have vegetable gardens and garden equipment to store, and who live on small acreages, drawing water from wells and using septic tank sewage disposal systems, have housing problems similar to those of farmers, and the housing research of the Department is applicable to them. Engineering research on design of equipment for the senior citizen is also needed.

In view of the continuing "cold war", consideration needs to be given to types of both farm and non-farm houses that would provide shelter from fallout if an emergency should develop. Basements could provide fallout shelter at small additional cost for families that do not have to care for livestock. On livestock farms, the family fallout shelter probably should be in the main livestock building.

## USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans for rural dwellings.

A. Design Criteria for Comfort, Health, and Safety. Research at Athens, Georgia, on determination and evaluation of thermal and sound effects of soft window and floor coverings, is in cooperation with the Georgia Agricultural Experiment Station. Development of planning aids at Athens, Georgia, is cooperative with the Georgia Station and at Beltsville, Maryland, with the Clothing and Housing Research Division, ARS.

B. Materials and Construction. Five experimental expansible houses at the Agricultural Research Center, Beltsville, Maryland, are under continuing evaluation of design, temperature control features and occupant reaction in cooperation with CH, ARS. An experimental structure for developing and evaluating low-cost floor deck and slab construction is located at Plant Industry Station, Beltsville, Maryland. Foundation construction suitable for expansive clay soils is under study at State College, Mississippi, in cooperation with the Mississippi Agricultural Experiment Station.

C. Systems for Environmental Control. A study to determine the optimum arrangement for an attic fan to reduce summer temperatures economically is underway at Athens, Georgia, in cooperation with the Georgia Station. An experimental, low-cost, plenum floor warm air heating system is being evaluated in one of the expansible houses at the Agricultural Research Center, Beltsville, Maryland.

D. Farmhouse Design Development. Architectural design and preparation of farmhouse plans for the Cooperative Farm Building Plan Exchange and related publications are carried on at Beltsville, Maryland, in cooperation with CH, ARS, and the Federal Extension Service. The State Agricultural Colleges cooperate through Regional Committees in establishing housing requirements and making the plans available to the public. Farmers Home Administration consults on requirements and makes plans available to its clients.

The Federal effort in this research area totals 5.9 professional man-years. Of this number 1.5 are devoted to design criteria for comfort, health, and safety; 0.7 to studies of materials and construction; 0.8 to systems for environmental control; 2.5 to development and preparation of improved farmhouse designs; and 0.4 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Although research in this area in past years has been most active in the State Agricultural Experiment Stations, investigation during this reporting period has been most limited by the agricultural engineers.

Leadership of programs of study has, for the most part, shifted to home economics with agricultural engineers providing largely consultation service.

A total of 0.2 man-year is devoted to this work.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Design criteria for comfort, health, and safety

1. Thermal control. At Athens, Georgia, studies to determine and evaluate the effects of soft window and floor coverings on heat loss in winter, heat gain in summer, and thermal environmental factors such as dry bulb temperature, radiation, and air motion in modern rural dwellings are underway. Several runs have been made with a control window in place and without window covering but the data have not been completely analyzed. All data are being taken with use of the data-logger, designed for the study, with IBM card output to minimize labor and errors in recording and analyzing.

2. Noise control. At Athens, Georgia, studies to determine and evaluate the effects of soft window and floor coverings on environmental noise levels in modern rural dwellings are continuing. Data on sound levels have been recorded for 24-hour periods in 19 of the 20 houses selected for the study. Tape recordings of the one-hour period having highest sound levels in each home have been taken for 18 homes. Analysis of a third of these tapes, at 1/3 octave band frequencies ranging from 125 to 16,000 cycles per second, shows the maximum sound levels thus far ranging from 72 to 84 decibels. These maximum sound levels at the various frequencies measured will be reproduced in a reverberation room which has been completed. There, sound decay can be measured with and without various window and floor coverings to determine the sound absorption caused by the treatment. Tests in the reverberation room will be started shortly.

3. Planning aids. Work on a series of short publications to serve as planning aids is continuing at Beltsville, Maryland, and Athens, Georgia. One on solar heat control and one on summer cooling have advanced to the final layout stage. Others--on insulation, wood framing details, foundation walls, and floor slabs--are in early stages of preparation. Still others have been assigned to staff members for preparation when work load permits.

### B. Materials and construction

1. Low-cost construction methods. Work was initiated at Beltsville, Maryland, to develop floor decks or slabs with improved characteristics over conventional concrete floor slabs. Three sections of deck, using organic materials, were installed in a 20- by 32-foot structure to study the effectiveness of a vapor protection system, installation techniques, and effects of several types of loadings. Readings are being taken on moisture and floor movement but have not yet been analyzed.

2. Foundations for expansive clay soils. At State College, Mississippi, work to develop designs for light foundations that retain position in expansive clay soils continued. An experimental device has been constructed to make comparative analyses of the movement of a conventional type block pier on a shallow footing and pressure treated wood piers footing on concrete at a depth of 4 feet. One wood-pier-on-concrete foundation is backfilled with soil, another with gravel, and the other with foamed-in-place polyurethane. Readings are being made with the device on Houston Clay. Sufficient data have not yet been accumulated for reporting.

#### C. Systems for environmental control

The study at Athens, Georgia, to determine the optimum arrangement of an attic fan in relation to the placement of roof or ceiling insulation for reducing summertime temperatures economically has been delayed due to difficulty in finding suitable cooperators. Necessary alterations are now underway in an existing house near Athens and studies will be started at the beginning of warm weather. The fan and louvers are automatically controlled to reduce human variables and temperatures will be recorded automatically.

Studies have been continued in expansible House D at Beltsville, Maryland. The plenum floor warm air heat distribution system, with narrow band discharge around the periphery of the room, provided uniform temperatures in the room and a warmer floor than the perimeter loop system in the other rooms of the house. Air entering the room is evenly distributed and annoying air currents are avoided. Cleaning is easier and the furniture arrangement can be more flexible because registers and radiators are eliminated. Occupants are also more comfortable at lower temperatures with this system because the exterior walls and floor are warmer and less heat is radiated from the body to these areas of the room.

Progressive improvements in wall insulation in the master and center bedrooms of House D were made and temperature studies conducted. When walls were insulated with as little as 2 inches of insulation, temperatures 4 inches above the floor were several degrees higher than before insulating and the temperature differential between floor and ceiling was reduced appreciably.

#### D. Farmhouse design development

Five farmhouse and recreation housing plans were developed at Beltsville, Maryland, and released between April 1, 1963 and March 31, 1964. One 3-bedroom plan of limited size was designed specifically to meet the needs of the Farmers Home Administration and the Southern Region Plan Exchange.

Another 3-bedroom plan of liberal size included the energy saving kitchen developed in cooperation with CH, ARS.

A fallout shelter plan was developed to be used as an integral part of new construction. (The man-years for this shelter are reported under Fallout Protection, 10 F).

Two "A" frame recreational cottages were developed as an aid to the Department's program on recreation and to meet requests of the Western Region Plan Exchange.

Two additional plans are now in preparation, including a low-cost, low-maintenance house for tenant and farm worker families. The latter is being considered by Farmers Home Administration for loan approval.

Plan suggestions for housing seasonal agricultural workers, incorporating construction requirements, are being developed for Farmers Home Administration. These will be guides for architects and builders of housing for these workers.

Plans for housing the senior citizen are being developed to meet requirements of Farmers Home Administration. These are guides for both single and multiple unit housing to be used by architects, builders and groups interested in senior citizen housing programs.

#### PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

##### Design Criteria for Comfort, Health, and Safety

Davis, C. P., Jr. and Simons, J. W. 1963. Farmhouse design and equipment for summer comfort. Agriculture Handbook No. 241. April.

Haynes, B. C., Jr. 1963. Automatic weather station. Georgia Agricultural Experiment Stations Technical Bulletin N.S. 33. December. 25 pp.

##### Systems for Environmental Control

Biggs, A. A. 1963. Fireplaces and chimneys. Farmers' Bulletin No. 1889. September.

##### Farmhouse Design Development

Agricultural Engineering Research Division. 1963. Five-bedroom farmhouse with basement. (Exchange Plan No. 7153). Miscellaneous Publication No. 946. December.

Agricultural Engineering Research Division. 1963. Fallout shelter for six people. (Exchange Plan No. 7166). Miscellaneous Publication No. 948. December.

## AREA NO. 9. LIVESTOCK ENGINEERING (EXCEPT ELECTRICAL)

Problem. The American farmer has about \$14 billion invested in service buildings and related structural equipment, over half of it for livestock facilities. Maintenance and new construction amount to another \$1.2 billion annually, again mostly for livestock facilities.

Economic conditions are forcing changes in the pattern of livestock production. Producers are trending toward fewer, larger and more specialized enterprises and toward "confinement" types of facilities in their effort to reduce production costs and improve product quality. These trends are demanding more basic knowledge about the effects of environment on the health, growth, production and fertility of livestock; about structures and related equipment for maintaining desirable environments; and about methods, structures and equipment for more efficient handling and feeding. The continuing threat of nuclear warfare demands consideration of types of buildings that will provide protection from fallout for livestock and their feeds, and provide facilities for operation during periods of emergency. (Fallout protection work reported in Area 10).

Much more needs to be learned in the laboratory on the relationships between livestock environment and disease transmission, feed conversion rates, and growth and production in order to determine optimum environments. Structures and equipment for economically providing these optimum environments under practical conditions need to be developed and field tested. Closely associated with the environment are flies and other insects, as well as parasites and diseases, that sap the vitality of animals and reduce their productivity. Pesticide residues in animal products are causing much concern. Information is needed on means for keeping these residues from adversely affecting the animals or their products.

Labor is an important element in production costs, and if only family labor is available, the labor requirement limits the size of enterprise. How to adapt existing buildings and other facilities for more efficient production, as herds and flocks are increased in size, or as farms are consolidated, is a major problem area. Cost of replacement or major improvement of existing buildings that are not suited to modern production methods are serious obstacles. Principles, examples and techniques for planning more efficient operations are needed both by farmers doing their own engineering and by those on whom farmers depend for advice.

Many types of structural and handling equipment such as feed bunks, self-feeding silos, and feeding floors, are important to livestock production enterprises. Adaptations and improvements to keep design of such equipment abreast of current production practices and buildings are essential to producers.

## USDA AND COOPERATIVE PROGRAM

This is a continuing program involving engineers and architects conducting basic laboratory investigations, application of laboratory results to a production basis, and development of typical plans for livestock structures. The work is in cooperation with the Animal Husbandry, Animal Disease and Parasite, and Entomology Research Divisions of ARS, USDA, and is a contributing project to Cooperative Regional Research Projects S-49, "Genetic Methods of Improving Dairy Cattle for the South", and NE-8, "Essentials of Poultry Housing for the Northeast". Plan development work is cooperative with all the State Colleges through Regional Committees, and with FES, as part of the Cooperative Farm Building Plan Exchange.

A. Dairy Cattle Engineering. Dairy cattle environmental and bio-engineering studies are conducted in a climatic laboratory at Columbia, Missouri, in cooperation with the Dairy Husbandry and Agricultural Engineering Departments of the Missouri Station. AH, ARS, serves in an advisory capacity. Field studies in a hot humid region are conducted at Tifton, Georgia, with the Georgia Coastal Plain Experiment Station and AH, ARS, cooperating. During the year the project engineer at Tifton was transferred to Davis, California, but cooperation will be maintained on an "occasional visit" basis. The influences of building arrangement, equipment, and chore routines on the amount and drudgery of dairy chores and means of improving these factors are studied in cooperation with the California Agricultural Experiment Station. Typical plans for dairy structures are developed at Beltsville, Maryland.

B. Beef Cattle Engineering. Beef cattle structures and equipment research for hot, dry climates is conducted in cooperation with the California Agricultural Experiment Station at the Imperial Valley Field Station, El Centro. Related studies for a warm humid climate are in cooperation with the Missouri Agricultural Experiment Station at Columbia, and with AH, ARS. (This work was inactive this year). Typical plans for beef structures are developed at Beltsville, Maryland.

C. Swine Engineering. Swine structures and equipment research is in cooperation with the California Agricultural Experiment Station at Davis and at the Imperial Valley Field Station, El Centro. Typical plans for swine structures are developed at Beltsville, Maryland.

D. Poultry Engineering. Poultry house environmental design criteria are investigated in controlled-temperature laboratory studies at Beltsville, Maryland, in cooperation with AH, ARS, and the basic laboratory data are applied to experimental poultry houses of the NE-8 Regional Project for evaluation.

Field studies on relation of housing structures to poultry disease are conducted in Mississippi in cooperation with the State Agricultural Experiment Station and AH, ARS. Environmental influences on health and housing are investigated in new laboratories at Athens, Georgia, and State College, Mississippi (under construction), in cooperation with AH and ADP, ARS, and the respective State Agricultural Experiment Stations. At St. Paul, Minnesota, a study of the role of environment in the prevention and control of chronic respiratory disease in turkeys is underway in cooperation with the Minnesota Agricultural Experiment Station. Typical plans for poultry structures are developed at Beltsville, Maryland.

E. Livestock Shades and Shelters. Shades for sheltering livestock are being studied at Tifton, Georgia, in cooperation with the Georgia Station.

F. Sky Radiosity Studies. Studies of sky radiosity (total radiation) are conducted at Davis, California, and at Columbia, Missouri, in cooperation with the respective Agricultural Experiment Stations.

G. Reducing Pesticide Residues in Animal Products. Reduction of pesticide residues in animal products, with beef cattle receiving major attention, is studied at Kerrville, Texas, in cooperation with ENT and ADP, ARS, and the Texas Agricultural Experiment Station.

Federal research effort in this area totals 9.6 professional man-years. Of this number 2.3 is devoted to dairy; 0.6 to beef; 1.3 to swine; 3.2 to poultry; 0.1 to shades and shelters; 0.4 to sky radiosity studies; 1.0 to reducing pesticide residues in animal products; and 0.7 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

There is an extensive program of both basic and applied research underway at the State Agricultural Experiment Stations in an effort to provide the answers to the continuing series of questions being raised by livestock producers. Demands are being made for more information on the effects of environment on the physical well being of all classes of livestock, and the way such optimum environments can be economically achieved; on new approaches to meet the growing labor shortage; on methods to adapt existing structures and equipment for greater economy of production; and on structures and related equipment for improved efficiency of feeding and materials handling operations.

Studies are being made of the effect of environment on the health, growth, production and fertility of dairy cattle, beef cattle, poultry and swine. Equipment and systems for efficiently transporting feedstuff into and out of storages and automatically mixing and feeding complete rations are being developed.

Exploring methods for improved care and housing of farm animals with greater economy and labor efficiency are also in progress as well as investigation of ways to modify existing structures and equipment to meet present-day economic conditions.

Much of this work is cooperative with the Department.

A total of 33.5 man-years effort is devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Dairy cattle engineering

1. Increasing efficiency of operations. At Davis, California, studies to determine the effectiveness of herringbone milking parlors in reducing the labor requirement in large-scale dairy enterprises were continued in cooperation with the State Agricultural Experiment Station. Time and travel required for the milking operation were measured on 7 more layouts, for a total of 48. Analyses to date indicate a big advantage in favor of using a milking machine head at each stall position in both stall rows of a two-row parlor as unnecessary delays due to slow milking cows can be avoided by a competent milking hand. The low-level milk pipeline has also shown the distinct advantage of reducing foaming in the pipeline and rancidity in the milk.

Preparation of a manuscript on milking facility layouts covering several years' study has proceeded to the final stage. Some of the principles covered have already been used as the basis for technical papers and other publications.

Farmstead planning, covering overall farmsteads, is discussed in Area 10 E.

2. Bio-engineering studies. Basic fundamental studies on the relationships between environment and various dairy animal health and production factors were continued in the psychroenergetic laboratory, and related facilities, at Columbia, Missouri.

Studies of acclimation of lactating Holstein cows to a hot environment were continued. A 2-year summary indicated milk production after 9 weeks of heat exposure (85° F.) was only 85 percent of that at base temperatures (65° F.), indicating inability to fully acclimate to the hot environment. The partial recovery in milk production and feed consumption was correlated with increases in heat dissipating functions and decreases in heat production to a level about 15 percent below that of the base condition (65° F., 50 percent relative humidity). Very little decrease of rectal temperature was observed to follow the initial rise during the 9-week exposure to 85° F. Glutocorticoid showed a gradual recovery during the period.

Inspired-air cooling was continued. Results of two years of investigations indicate a high degree of response, although benefits to the animals were slightly below those provided by cooling the total environment to a 65° F., 50 percent R.H. condition. For lactating Holsteins housed in an 85° F., 50 percent R.H. room environment during the first year's test, milk production expressed as a percentage of expected values at a base condition (65° F., 50 percent R.H.) averaged 73 percent when inspired-air was 85° F.; 91 percent when inspired-air was 60° F.; and 90 percent when inspired-air was 50° F. Breathing heated air (85° F.) in a cool room environment (60° F.) depressed milk production and feed consumption, while respiration rates and rectal temperatures remained essentially at "normal" levels. Results of the second year's tests have not yet been analyzed.

Physiological evaluation of dairy cows as part of a long-range evaluation of physiological responses to standardized environmental conditions, was continued at Missouri. Responses of the six individual cows tested this year were more uniform than groups tested in the prior 2 years. At the standard environmental condition of 88° F., 40 percent R.H., maximum differences among individuals were 1.9° F. rectal temperature, 23 respirations/minute, and 10 heartbeats/minute.

Heat sensitivity of lactating cows was studied with cows in a single-cow hot box designed to provide a constant 110° F. air temperature. The measure of sensitivity used is the length of time required to cause a rectal temperature rise of 2° F. This is part of a continuing study at Missouri and past data have not yet been analyzed.

Air conditioning of dairy barns is under study in Missouri. Limited data were obtained during a one-month preliminary test of an air-conditioned tie-stall barn. Two groups of 16 lactating Holsteins were used, one housed in the barn and the other in a drylot outside, on an alternate 2-week basis. There was no marked improvement in milk production, although a slight trend favorable to the air-conditioned barn was noted. However, natural conditions averaged 1.5° F. below normal during the August run--with both maximum and minimum temperatures during the month being unseasonably moderate.

Production methods for cooling dairy cattle were studied at Tifton, Georgia, an area representing hot-humid climates. The value of shade, and shade in combination with fans and water sprays, was investigated. Two groups of nine Jersey cows were held in drylot at all times (except for milking) with these two treatments, from June 16 to August 21, 1963. Cows on the shade plus fans and sprinklers treatment experienced a daily decline in milk production of 0.185 pounds compared to 0.196 pounds for the cows on the shade only treatment. These declines are somewhat larger than those found in previous studies; however, this might be expected since the average daily milk production of 39.2 pounds for the shade only treatment and 41.0 pounds for the shade plus fans and sprinklers was considerably higher than for previous studies.

3. Plan development. At Beltsville, Maryland, special studies were made of plans for free-stall housing for dairy cattle and working drawings were developed for the construction of the stalls and for the layout of a complete dairy operation incorporating this type of housing, to meet the demand brought about by the growing acceptance of this practice. Working drawings were also prepared for an open-front, individual pen type dairy calf barn and for a tilting calf table. Also, three designs were prepared for dual-purpose fallout shelter-dairy housing structures. One of these is planned to keep construction costs as close as possible to those for a conventional stall barn. Radiation protection is provided in the stall area, milkroom and personnel quarters by earth-banked walls, heavy mow floor, location of silos, and use of stored feed and bedding. The other two are for free-stall barns intended for use with loose housing systems. Radiation protection is provided by earth bank shielding around the buildings and by using a washdown system to prevent the accumulation of fallout on the roof. This permits use of low cost pole-type construction and lightweight metal roofing. The latter two do not include personnel shelters. (The man-years for the dual-purpose structures are reported under Fallout Protection, 10 F).

All these plans are included in the Cooperative Farm Building Plan Exchange.

#### B. Beef cattle engineering

1. Hot, arid climates. At the Imperial Valley Field Station, El Centro, California, in cooperation with the California Agricultural Experiment Station, three pens of beef cattle were used to study the effects of floor slope on weight gain, activity, and manure removal. In one pen the floor was level, in the second at a slope of  $4 \frac{3}{4}$  percent and in the third at 7 percent. Average daily gains during each of 6 test periods were:

Period days	Slope		
	I (7%)	II (level)	III ( $4 \frac{3}{4}$ %)
28	0.83	1.80	1.18
29	2.39	1.75	2.81
28	1.65	1.49	1.59
27	2.26	0.83	1.81
28	2.73	2.69	2.87
28	1.31	0.94	1.06
Average	1.86	1.59	1.90

Manure moved readily down both the sloping floors because the pens were completely shaded and the manure did not dry out. Actually, it was planned that the animals would work the manure downhill as they walked to the upper side to the feed trough. This probably would occur if the pens were not so shaded and the manure had a chance to partially dry out. During some periods of the next test, these pens will be unshaded.

Activity studies showed the following percentages of time lying, standing, and eating:

	Pen	Lying	Standing	Eating
		percent	percent	percent
8/22-23	I	33	57	10
	II	46	43	11
	III	52	35	13
9/3-4	I	51	38	11
	II	27	65	8
	III	53	36	11
10/13-14	I	55	36	9
	II	28	66	6
	III	46.5	47	6.5

Animals on the level floor did not lie down as much because the floor was much dirtier. Pen I cattle had the smallest gain the first 28-day period, and activity studies showed them to be standing a high percentage of time. The general idea seems to work fine and these exploratory tests, along with the associated activity studies, indicate possibilities for improvement and also for application. The labor of manure removal always seems to be high.

An air-conditioned "Reference House" has been designed for the Imperial Valley Field Station and will be constructed sometime during the next year. It will be pre-fabricated, metal, and approximately 35 by 65 feet with pens for 12 animals in individual stalls.

2. Hot, humid, climate. Inactive during reporting period.

3. Plan development. At Beltsville, Maryland, working drawings were prepared for four plans covering the layout and construction details pertinent to modern range corrals for beef cattle based on field studies of successful operations. Also a design was completed for a bunker type shelter with protection features for fallout. A pressure-treated wood frame supports an earth cover overhead and on three sides. Baled hay stacked at one end provides shielding and feed for approximately two weeks. (The man-years for this plan are reported under Fallout Protection, 10 F).

All these plans are included in the Cooperative Farm Building Plan Exchange.

### C. Swine engineering

1. Effect of humidity on swine. Swine humidity-growth studies are being continued at Davis, California, in cooperation with the California Agricultural Experiment Station. Four pigs, weighing 20 pounds each were placed in each of three 20-square foot chambers in which the temperature-humidity-index (THI) and relative humidity (RH) were programmed in accordance with the following, up to market weight (200 pounds):

Weight, pound		50	100	150	200
Group I	THI	72	70	68	66
	RH, %	88	64	39	15
Group II	THI	66	68	70	72
	RH, %	15	39	64	88
Group III	THI	72	72	72	72
	RH, %	88	88	88	88

The results were:

	Group I	Group II	Group III
Average daily gains, lb.	1.43	1.34	1.35
LB feed/lb. gain	3.68	3.83	3.84

This test was repeated, using only three pigs per chamber, starting at 65 pounds and running to 212 pounds. The RH of each chamber was held constant throughout the test and the dry bulb temperatures were kept at the optimum values for the average weight of the pigs. The results were:

	Group I	Group II	Group III
RH, %	45	70	95
No. days	99	99	99
No. pigs	3	3	3
Total gain, lb.	140	146.7	154.3
LB feed/lb. gain	3.71	3.67	4.16

The differences in gain and feed conversion were not statistically significant.

2. Hot, arid, climate. At Davis, California, in cooperation with the California Agricultural Experiment Station, studies of sprinkler operation continued in a program to determine nozzle size and operational times to give the most efficient use of water for cooling pigs stressed by hot weather.

During the summer months, starting on June 24, 1963, a 78-day trial was run with five groups of ten pigs each, studying the comparative value of nozzles. The results were as follows:

	Control Group no spray	4.6 $\frac{1}{15:15}$ Nozzle Min.on:Min.off	4.6 $\frac{1}{Continuous}$ Nozzle Spray	6.4 $\frac{1}{15:15}$ Nozzle Min.on:Min.off	6.4 $\frac{1}{Continuous}$ Nozzle Spray
No. of pigs	9	10	10	10	9
Total gain, lbs.	113.8	122.9	117.0	122.0	110.8
Av. daily gain, lbs. per pig	1.46	1.58	1.50	1.56	1.42
Av. daily feed, lbs. per pig	6.86	6.64	6.16	6.87	5.97
Feed/unit gain, lbs.	4.89	4.22	4.10	4.39	4.29

$\frac{1}{15:15}$  Gallons per minute at 100 lb. per sq. in. pressure

None of the differences between these groups was statistically significant.

At El Centro, California, the third in a series of three tests with air conditioning for pigs showed gains of 1.70 lb./day with feed and water inside the air-conditioned house, 1.65 lb./day with feed and water outside the air conditioned house, and 1.55 lb./day with a shaded wallow. Analyses of the three years' data indicate a significant increase in daily gain and daily dry matter consumption over the control group for those animals with the cooled house having feed and water inside. There were no significant differences between the gains of the groups in the cooled houses. The results are shown in the following table:

Comparisons of Air Conditioned Houses with a Shaded Wallow for Fattening Hogs (3 Years Data)

	Air Cooled House		Shaded
	Feed and water inside	Feed and water outside	Wallow
No. of animals	24	24	24
Initial wt., lb. $\frac{1}{1}$	78	79	78
Total gain, lb. $\frac{1}{1}$	133	130	124
Daily gain, lb. $\frac{1}{1}$	1.73	1.69	1.61
Daily feed, lb. $\frac{1}{1}$	5.71	5.43	5.27
Feed/100 lb. gain $\frac{1}{1}$	330	320	327
Yield $\frac{1}{1}$	69.0	67.0	67.3
Backfat, in. $\frac{2}{1}$	1.90	1.80	1.75

$\frac{1}{1}$  Average of Trials I, II, III (1961, 1962, 1963)

$\frac{2}{1}$  Average of Trials I and II. Slaughter data from Trial III were lost due to inability to positively identify all animals after slaughter.

The necessity to recirculate the cooled air to maintain the low (70° F.) temperature in the cooled house uncovered a possible source of problems to be solved if air conditioning of animal shelters is practiced commercially. The floor of each house was relatively dry and the amount of dust collected on the return air filters was considerable. The average weight of dust collected was determined for weekly periods when the hogs weighed about 130 pounds and again as they approached 200 pounds. The two 20" x 20" filters (in series) on the house with the feed and water outside stopped a total of 20 grams/day and 40 grams/day at the weights indicated. When the feed and water were inside the house the amount of dust collected averaged 41 grams and 70 grams/day, respectively, at the two weights. Where the feed and water were outside, there was much more movement in and out by the pigs and consequently more dust causing materials being tracked in and being caught by the filters. The average composition of the collected material for each house is shown in the table. Two sets of filters for each house were necessary because almost daily changes were required to keep the heat exchanger from becoming plugged.

Composition of the Dust Collected on the Return Air Filters 1/

Source	Ash %	Silica %	Nitrogen %	Ether extract %	Crude fiber %	Lignin %
Cooled house (feed and water inside)	13.6	3.6	4.5	3.9	6.7	2.4
Cooled house (feed and water outside)	30.5	10.8	5.5	3.4	5.8	4.9

1/ Other constituents of dust not measured

3. Hot, humid climate. Studies on the value of shade and shade plus fogging for pigs and sows in hot, humid climates were continued at Tifton, Georgia. The same movable shades on skids and lots were again used in 1963. Forty pigs (average 53.5 pounds each) were held in small pasture lots (10 pigs per lot); two lots had shade plus fogging under the shade and two lots had shade only. An analysis of variance indicated a highly significant difference in rate of gain at the .01 level due to the fogging treatment. However, there was no significant difference in feed efficiency.

Sixteen bred sows and sixteen bred gilts were in temporary pasture lots (8 animals per lot); two lots had shade plus fogging under the shade and two lots had shade only. Average rectal temperatures and respirations per minute (on selected days) for the animals having access to the shade and fogging were  $100.8^{\circ}$  and 34.2, respectively, while the same measurements for the animals having shade only were  $102.9^{\circ}$  and 113.5, respectively. However, the average number of live pigs farrowed, birth weight of live pigs, number of pigs weaned and adjusted 56-day weight of pigs appeared to be equal for the two treatments. This is the second year's data and it is estimated that approximately four years' data will be required for analysis.

4. Level of feeding. At Escalon, California, studies on level of feeding of pigs were continued as an extension of a previously reported housing study. A cooperative experiment with a major producer involved the effect of limited feed intake on feed utilization. Three pens of 10 crossbred pigs each were placed on a daily feed intake of approximately 70 percent of NRC recommendations, three pens on approximately 80 percent, and three on approximately 90 percent, on April 15, 1963. The high level pigs were slaughtered July 23, the medium level on July 30 and the low level on August 13. These animals were slaughtered as they reached the same average weight of pig per feed level. The gains varied, as would be expected, according to the amount of feed. However, when the gains were adjusted by co-variance to equal feed consumption there were no significant differences, indicating that gross feed utilization did not differ between groups. There was a significant difference, however, in the specific gravities of the different groups and the specific gravities were inversely proportional to the level of feed consumption, as would be expected. Further analysis needs to be made to determine the utilization of energy.

5. Stand-up feeding. At Davis, California, in cooperation with the California Station, studies of stand-up feeding were continued with third and fourth replicates. The third extended from June 18 to September 30, 1963, with 2 pens of 11 pigs each (69 pounds average weight). One pen was control with a flat wood feed trough on the ground (12 feet long with 8-inch openings). The second had two 8-foot standup feeders. Aluminum shades were constructed to cover the feeders in each pen. There were no differences in total gain, average backfat thickness, specific gravity, weight of ham, percent of ham, weight of loin, or percent of loin. In cooperation with the Anatomy Department of the Veterinary School, some 18 individual muscles or muscle groups were dissected from the hind leg of one side of each hog carcass. These data have not been completely analyzed as yet. A fourth replicate was initiated on December 30 with the following treatments: control pen, 11 pigs eating from flat troughs on the ground; early standup, 10 pigs eating from standup feeders at start of test; late standup, 10 pigs eating from ground troughs to 130 pounds, then from standup troughs. The pigs weighed about 79 pounds at the start. Data from these tests have not been completely analyzed.

6. Slatted floors. Studies on the use of slat-feeding floors for swine are being conducted in cooperation with the Northeast Experiment Station, Duluth, Minnesota, to determine the material best suited for this type of floor; to determine the effect of this type structure on the labor requirements for caring for the animals and on animal health and feed efficiency. The first year's results indicate the wood slats are showing wear, particularly in the vicinity of the waterers. Present estimates are that they will have to be replaced after about three years of use. There is no evidence of wear on the steel or concrete slats. The slat-type floor was found to reduce the amount of labor required for manure removal. The saving amounted to 20 to 40 minutes per day per 100 hogs from that required for washing off the solid feeding floor. There was no apparent difference in animal health or feed efficiency. Visual observations during hot weather indicated a tendency for the animals to appear more comfortable on the slat floor.

7. Moisture loss. Studies on swine moisture loss were initiated at Davis, California, in the controlled-temperature laboratory, to try to develop a method of separating swine moisture loss into skin loss and respiratory loss. A restraining frame was designed inside a plexiglas tent (air tight) and a mask was designed to fit on the head. Total moisture loss is measured from the pig in the tent without the mask. With the mask on, skin moisture only is measured. Six crossbred pigs were trained to enter the tent and have the mask fitted over their heads. Tests are now in progress and the results look promising for developing workable techniques.

8. Plan development. No plans for swine structures were prepared during the year.

#### D. Poultry engineering

1. Calorimeter studies. Investigations to determine heat and moisture production of broilers were continued in the respiration calorimeters at Beltsville, Maryland. Analysis of data from a series of 9-week tests of Athens Randombred broilers in the calorimeters at 5°, 10°, 25°, and 30° C. showed that the total heat production peaked at about 20 to 23 Btu/hr/lb. live weight between 12 and 15 days of age. In contrast, previous tests with growing NH chicks on litter showed that the heat production peaked 10 to 15 days later at about the same value. Development of the homeothermic ("body thermostat") mechanism in modern strains of broilers appears to be accelerated, and current brooding temperature reduction regime may need revision. Latent heat production ranged from 3 to 5 Btu/hr/lb. live weight near day-old age and gradually decreased to 2 to 3 Btu/hr. near 40 to 45 days of age. Sensible heat production ranged from 6 to 18 Btu/hr/lb. live weight near day-old age. The higher value was obtained at 95° F. and the lower one near 91° F. Huddling of chicks at the lower temperature may have decreased the heat output.

It appears that fecal moisture content of broilers is around 80 to 83 percent on a wet basis. Although the growth of the Athens Randombred broiler stock in the calorimeter was not spectacular, basic engineering data on water to feed ratio and water plus feed to fecal production will be usable. These data need to be applied to an instrumented broiler house to test the suitability of the laboratory data for engineering design data. In a 3-day test of broilers after the 9-week age, birds which had been at 51° F. and 75 percent RH panted when placed in the calorimeter at 77° F. and 76 percent RH. Another group of broilers, which had been at 77° F. and 76 percent RH, when exposed to 51° F. and 75 percent RH increased sensible heat output by about 1/3, and seemed to be "uncomfortable". Further analysis is needed to assess the implication of sudden weather changes in a broiler house.

2. Southeast poultry disease laboratory. The facility at Athens, Georgia, was just made available during the year so considerable engineering time was spent on design and installation of laboratory and shop equipment and instrumentation. A prototype cabinet, to be used as a laboratory tool in the study of the relationship between environment and disease, was substantially completed and some performance tests were conducted. In addition, specifications have been prepared for materials and equipment required for operation of the laboratory buildings, but which were not included in the construction contract. These total in excess of \$100,000.

3. Field observation on relation of housing to disease in the South Central States. Work at State College, Mississippi, in cooperation with Animal Husbandry Research Division and the Mississippi Station, has continued.

Insulation in the roofs of broiler houses has had mixed effects on production results of broilers. Insulated houses did not always produce the largest average weight, the highest feed efficiency, or the lowest condemnations--largely because of differences in management techniques from one house to another. These differences make it impractical to draw firm conclusions from the data to date.

Orientation of the houses showed little effect on the production of broilers. The north-south house receives more direct radiant heat than the east-west house in both winter and summer. The average weight, feed conversion, and condemnations, however, have been about the same in both the north-south and east-west oriented houses.

Temperature data show that the brooder does not maintain a uniform temperature under the hover. This was true of the gas hover and the hot water brooding systems, which were the only ones studied. This could be caused by a faulty thermostat or one that has been in use too long and is not as sensitive as it should be.

Investigation of the effects of curtain materials on environment within a broiler house showed a wide variation in the amount of radiant heat that can be transmitted through the different materials.

4. Influence of turkey housing environment on disease. Work at St. Paul, Minnesota, in cooperation with the Minnesota Station, has continued. The original objective was to determine how varying environments affected the course of airsacculitis disease in turkeys. During the past year breakthroughs in egg dipping procedures have made possible the purchase of poults free of the S<sub>6</sub> strain of Mycoplasma gallisepticum. The engineering objective of the project, therefore, has changed to one of maintaining a disease-free environment. This calls for isolation measures to prevent entry of disease from outside sources and elimination of environments that might produce stresses. Equipment studies are being conducted parallel to the disease studies.

Two flocks of broiler turkeys have been grown to maturity from dipped eggs. The last flock grown during the coldest season of the year had few condemnations, none from airsacculitis. A salmonella outbreak was finally traced to field mice which had moved into the building at the onset of cold weather.

High concentrations of ammonia remain a problem. The addition of supplemental heat has been necessary in all pens to keep the litter in acceptable condition. The higher temperatures, however, seem to favor the production of ammonia. The drying of the litter, although better at an elevated temperature, never got the litter dry enough to decrease the ammonia production.

Several types of brooders have been tried in the course of the experiments. Losses have varied from 1 percent to 40 percent. Homemade hovers over hot water finned radiators and infrared heat lamps have given the best performances so far.

5. Plan development. No plans for poultry structures were prepared during the year.

#### E. Livestock shades and shelters

At Tifton, Georgia, in cooperation with the Georgia Agricultural Experiment Station, a study was continued in an effort to define the best height for cattle shades in a hot, humid climate such as the Southeastern United States. Three shades, 12 by 24 feet, were erected--at heights of 6, 9, and 12 feet, each covered with galvanized metal. Black globe and shielded air temperatures were recorded on various days at the animal level.

Directional radiometer traverses were made under the 6-foot and 12-foot shades. The average black globe temperature was reduced  $19.6^{\circ}$  F. under the 6-foot shade and  $17.5^{\circ}$  F. under the 12-foot shade at an air temperature of  $89.3^{\circ}$  F. and an unshaded black globe temperature of  $114.2^{\circ}$  F. The average radiant heat load was 172.8 Btu/hr/sq.ft. under the 6-foot shade and 179.9 Btu/hr/sq.ft. under the 12-foot shade. It was concluded that the radiant heat load on animals in the Southeast is greater under high shades than under low ones, and there is no thermal comfort advantage for shades over 6 feet high. Also, it seems reasonable to expect that the amount, frequency, and type of clouds would dictate the optimum height of shades in a particular area.

#### F. Sky radiosity studies

At Davis, California (dry climate, clear sky) and at Columbia, Missouri (humid climate, overcast sky), in cooperation with the respective Experiment Stations, a study was continued for the purpose of measuring the downcoming radiant fluxes from various parts of the sky. The quantity, quality, and variation of these fluxes with azimuth and altitude are needed because of their effect on the design and orientation of farm shelter and storage buildings.

At Davis, California, two directional radiometers were mounted so that vertical and horizontal angles defining their direction could be quickly determined. A high-quality quartz filter was obtained along with its transmission curves. One radiometer will be filtered to cut out all radiation beyond 5 microns. The other will measure total incoming radiation. This should allow separation of incoming radiation into "long" and "short" wave. A normal incidence radiometer was purchased for use in determining sky condition.

U.S.D.A. is cooperating with the California Station in a project to obtain data on heat transfer to the celestial cold sink. Four weather stations have been completed and each has a radiometer that reads a spot  $60^{\circ}$  above the horizon in the North sky. One was placed in operation at Davis in March 1963 (elevation 56 feet), the second on April 19 at the Bishop Airport (elevation 4,136 feet), and the third at White Mountain Crooked Creek Station on July 4, 1963 (elevation 10,250 feet). The fourth is a standby station. The Davis and Bishop stations operated during the winter; the high-elevation station was dismounted about November 1. Data obtained are being analyzed by the California Station and will be available and usable for the sky radiation measurements.

At Columbia, Missouri, efforts are on improving instrumentation. A pyrheliometer was mounted in a housing to limit its field of view to that of a directional radiometer, then both were mounted and aligned on a common shaft on an engineer's transit chassis to provide accurate azimuth and elevation angles. A camera mount on the same shaft allows pictures to be taken of what the instruments are viewing. This should allow determination of the effects of clouds and "short" and "long" wave radiant fluxes from the sky and surroundings during the coming year.

#### G. Reducing pesticide residues in animal products

Development and testing of automatic sprayers for cattle were continued because the experimental devices offer methods of providing practical and efficient control of flies with fewer residues of insecticides in meat and milk than other spraying equipment. Work is cooperative with projects ENT-h2-1, "Development of Insecticides, Repellents, and Other Materials and Methods for the Control of Horn Flies, Stable Flies, and Face Flies" and ENT-m11-2, "Development of Methods of Analysis for Insect Control Chemicals". Laboratory tests with the experimental sprayers indicated that residues of the insecticides, D.D.T., Ronnel, and G.C. 4072, left in milk by the low volume treatments, were significantly less than those of more conventional high-volume treatments. Daily automatic sprayer treatments of 80 to 120 ml. (.02 to .03 gal.) left residues not exceeding four parts per billion in milk. Concentrations that were approximately as effective as more conventional 1/2 or 1 gallon treatments left only 0.7 to 2.5 percent as much residue.

Field tests conducted during the summer of 1963 indicated that the low-volume application of Ciodrin (Shell 4294) by the experimental sprayers provided satisfactory control of horn flies on cattle. The data verified the conclusion, reached during the previous year, that the experimental sprayers controlled horn flies as well as more conventional equipment with significantly less insecticide. Operation of the sprayers under field conditions provided detailed information useful in establishing guidelines for the design of sprayers or other equipment for the self-treatment of cattle. A number of modifications with simplified and improved design were developed.

A simplified procedure for measuring the quantity of Co-Ral on the hair of treated livestock was developed in cooperation with project ENT-m11-2. The simplified procedure was used for determining the distribution of spray on a cow treated by an experimental automatic sprayer. Preliminary analysis of the results indicated that the method was quite suitable for evaluating boom and nozzle systems.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Dairy Cattle Engineering

Agricultural Engineering Research Division. 1963. Three-stall milking plant for 20 to 40 cows. (Exchange Plan No. 5875). Miscellaneous Publication No. 937. June.

Agricultural Engineering Research Division. 1963. Hay storage and feeding shed. (Exchange Plan No. 5935). Miscellaneous Publication No. 938. July. (Also listed under B, Beef Cattle Engineering)

Agricultural Engineering Research Division. 1963. Dairy barn fallout shelter. (Exchange Plan No. 5937). Miscellaneous Publication No. 943. October.

Bond, T. E., Ota, H., Hahn, G. L., and Yeck, R. G. 1964. Environmental control for animals and plants. ASHRAE Guide, Applications Volume, Chapter 31, pp. 353-380.

Hahn, G. L., Johnson, H. D., Shanklin, M. D., and Kibler, H. H. 1963. Responses of lactating cows to inspired-air cooling in a hot environment. Journal of Animal Science 22:824.

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The following cooperators' publications are the results of cooperative work and report related non-engineering phases of the research:

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Lundgren, R. G., and Johnson, H. D. 1964. Effects of temperature and control feeding on I<sup>131</sup> disappearance rates of dairy cattle. Journal of Animal Science. February.

Yousef, M. K., Johnson, H. D., and Kibler, H. H. 1963. Development of helmet for indirect calorimetry system utilizing gas chromatography for cattle. Journal of Animal Science 22:867.

### Beef Cattle Engineering

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Zeller, J. H., Bond, T. E., and Petersen, G. M. 1963. Hog lot equipment. Farmers' Bulletin No. 2192. July.

### Poultry Engineering

Griffin, Jack G. 1963. Trends in broiler housing. Broiler Business, Volume 14, No. 4. April.

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Ota, Hajime and McNally, E. H. 1963. Heat dissipation studies of Arizona and Beltsville bred strains of SCWL. Poultry Science 42:1289-1290 (abstract).

Ota, Hajime and McNally, E. H. 1963. Poultry studies with respiration calorimeters. ASAE Transactions 6:129-131.

Livestock Shades and Shelters

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Hahn, G. L., Bond, T. E., and Kelly, C. F. 1963. Walls influence interior radiant environment of livestock shelters for shade. California Agriculture 17(9):10-11. September.

Reducing Pesticide Residues in Animal Products

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AREA NO. 10. CONSTRUCTION STANDARDS, WATER SUPPLY, WASTES  
DISPOSAL, AND FARMSTEAD PLANNING

Problem. Farm buildings inventoried at \$28 billion in the United States are the production, storage (and sometimes the processing) centers of food and fiber for the nation. Annual cost of repair, remodeling and new construction of the farm plant amounts to \$2 billion, an expenditure that may wastefully use materials through lack of sufficient knowledge of the loadings to which buildings are subjected--the pressures of soil movement, wind gusts, snowfalls, and stored product loads.

Construction may be wasteful because we lack knowledge of design methods for inherently strong shapes such as hyperbolic paraboloids. Our knowledge of materials and materials fastening is incomplete and often inaccurately used in special applications encountered in livestock production.

Product application research stimulates the economy of manufacturers of building products (lumber, steel, cement, plastics, asphalts, aluminum, inorganics), building fabricators, farm producers and the general consumer. Research is needed on loads imposed on buildings by nature; properties of materials for strength, weathering, aesthetics and durability; and the proper combination of materials of construction for the most economical and effective structures.

In many localities urban building codes that may be unduly restrictive are being extended to cover farms, where the hazards of public occupancy and damage to the property of others are not present to the degree that they are in urban areas. Those who draft building and fire codes need design information that would be realistic for farms.

An adequate supply of satisfactory water is essential to the farmstead. Automatic running-water systems, more water-using equipment, new uses for water, higher standards of sanitation, and other factors are continually increasing the demand for water on the farmstead--both in quantity and quality. The "old well" is less and less able to satisfy the demand. Some farm operators have been forced to buy water by the tank or truck load at considerable cost; others are developing farm ponds as sources of farmstead water; some continue to operate with a supply that is becoming less and less adequate.

Surface waters normally require disinfection to guard against water-borne diseases such as typhoid, dysentery, other gastro-intestinal disorders, and infectious hepatitis. Often they also require filtration and other treatment to remove undesirable foreign material. Deeper ground waters are often highly mineralized (hardness, iron, sulphur, and others), and expensive or impossible to treat adequately. Pesticide chemicals are beginning to show up in both surface and ground water supplies. Data on water demands and water systems requirements of the modern farmstead are needed to guide farmers in planning water systems and selecting equipment, to enable extension workers to adequately advise farmers, and to guide equipment and appliance manufacturers and sanitary code-making bodies. Simpler, more reliable, and less costly methods and equipment are needed for treating farmstead water supplies to improve their quality.

Disposal of organic wastes--principally sewage and manures--is becoming more and more of a problem on the modern farmstead. The cattle, hogs, horses, sheep, and poultry on farms in the United States produce more than 2 billion tons of manure annually. The problem is particularly acute with respect to confinement-type livestock operations on the fringes of metropolitan areas--where the total amount of manure is concentrated in the confinement area. Under these conditions, it is difficult to avoid creating a sanitation hazard or a public nuisance. Economical, sanitary means of disposition need to be developed. Among means that need to be investigated are lagoons, irrigation systems, subsurface absorption systems and reclamation. Development of improved methods for disposing of sewage in those rural areas where conditions are adverse to the conventional septic tank system (high ground water, shallow rock, non-absorptive soils, restricted areas) is needed.

The arrangement plan of the farmstead has an important bearing on its efficiency, appearance, and livability. For example, convenient locations for feed and bedding storage ease the distribution chores. A 40-cow dairy herd will use approximately 240 tons of silage, 60 tons of grain, 40 tons of hay, and 20 tons of bedding annually. Research is needed to evaluate the various planning factors in the light of current equipment and practices and to develop planning principles and guidance materials for the benefit of farmers--particularly those contemplating changes.

#### USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in basic and applied research on structural aspects of farm buildings, farmstead water supply, farmstead wastes disposal and farmstead planning. Protection of farm families and animals against radioactive fallout has recently become of concern. The program is cooperative with selected State Agricultural Experiment Stations and other appropriate agencies.

- A. Meteorological factors affecting the design of farm structures, such as climate and weather (wind, storms, frost, etc.), are studied at Beltsville, Maryland, and selected field locations.
- B. Construction Standards, such as serviceability and safety, for design of farm buildings are studied at Beltsville, Maryland, and selected field locations. Liaison is maintained with the American Society of Agricultural Engineers, American Standards Association, National Safety Council, National Fire Prevention Association, and other organizations concerned with standards and safety in farm structures.
- C. Materials and Construction Methods for farm buildings are studied at Beltsville, Maryland; at Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station; and at State College, Mississippi, in cooperation with the Animal Husbandry Research Division and the Mississippi Agricultural Experiment Station.
- D. Water Supply and Wastes Disposal for the farmstead are studied at College Park, Maryland, in cooperation with the Maryland Agricultural Experiment Station. Liaison is maintained with the Public Health Service, the Water Systems Council, the American Society of Agricultural Engineers, and other organizations concerned with rural sanitation.
- E. Farmstead Planning studies are made at Beltsville, Maryland, at St. Paul, Minnesota, in cooperation with the Minnesota Agricultural Experiment Station, and at Davis, California, in cooperation with the California Agricultural Experiment Station.
- F. Fallout Protection work for the farmstead is conducted at Beltsville, Maryland, and selected field locations. Liaison is maintained with the Office of Civil Defense, Department of Defense, and other appropriate agencies.

The Federal effort in this research area totals 7.6 professional man-years. Of this number 0.3 is devoted to meteorological factors; 0.4 to standards for serviceability, safety, etc.; 1.8 to materials and construction methods; 2.2 to water supply and wastes disposal; 0.9 to farmstead planning; 1.4 to fallout protection; and 0.6 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is confined largely to basic and applied studies of structural components for farm buildings; techniques and systems for adequate and safe water supply; and improved methods for economical and sanitary disposal of organic wastes on the modern farmstead.

Representative of the investigations currently in progress in the farm buildings field are those which are concerned with analysis, design and testing of rigidly connected frames and panels; studies of single cover stressed skin designs for clear span roofs; development of wall and roof designs to resist storm damage; tests of the structural stability of farm buildings under accelerated cycles of loading and adaptations of new construction techniques to problems of farm service buildings and animal shelters.

In the water supply area research is underway to develop ways to economically filter and treat surface waters in order to provide an adequate and sanitary quantity of water for the farmstead operations. Studies are also being made on the problems concerned with demineralizing deeper ground waters.

A widespread research effort is in progress which is attempting to investigate all of the factors involved in the complicated problems concerned with disposal of farm waste materials, particularly concentrated manures resulting from confinement-type livestock operations. The problem is most acute and the public is demanding a fast solution to this unsanitary and potentially dangerous health hazard.

Much of the work in this area is cooperative with the Department.

A total of 27.8 man-years of effort is devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Meteorological factors

At Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station, a 20- by 30-foot test structure is being set up and instrumented to measure the magnitude and distribution of natural wind loads on farm structures. The test structure is being mounted on a turntable to permit changes in the impinging angle of the wind. It will be possible to measure pressures on a structure in short-time intervals; making it possible to plot frequency of dynamic pressure cycling brought about by natural winds.

##### B. Construction standards

At Beltsville, Maryland, proposed design loads for farm structures were developed from analysis of the snow load probability data previously obtained from the U. S. Weather Bureau. These proposals were accepted by the Construction Standards Committee of the American Society of Agricultural Engineers with no dissenting votes. This new concept of design wind and snow loads based on probable intervals of recurrence represents a significant improvement over previous knowledge on snow loads.

At Beltsville, Maryland, appreciable effort was devoted to liaison and coordination with the ARS Safety Council, the Federal Safety Council, the National Fire Protection Association, and the American Society of Agricultural Engineers on preparation of fire and safety guidance materials for use by architects, engineers, safety planners and others requiring technical information in this field.

C. Materials and construction methods

1. Stressed-skin panels. Field work on this project, at Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station, was completed during the year. Data are being prepared for publication.
2. Hyperbolic paraboloid (HP) shapes for farm structures. At Beltsville, Maryland, testing of various materials shaped into hyperbolic paraboloids has continued. An experimental triangular HP roof unit was completed and put on test in November 1963. It withstood, without damage, 8-inch and 10-inch snowfalls and a 50-mph wind that occurred during the winter. The unit is designed to be the first stage of a twin-unit structure and is being used as a "case study" to test and evaluate fabrication details. Design improvements suggested by service performance of the first unit will be incorporated in the second.
3. Rotational strength of nailed joints. Field work on this project, at Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station, was completed during the year. Data were prepared for publication.
4. Plan development. Plans developed for crop structures, farmhouses, livestock structures, and fallout protective structures are reported in Areas 7, 8, 9, and 10 F.

D. Water supply and wastes disposal

1. Farmstead water requirements. Studies on farmstead water demands and requirements are continuing in Maryland, in cooperation with the Maryland Agricultural Experiment Station. Water usage data were recorded on 7 farms and furnished valuable information on limitations imposed on water systems by unrealistic design recommendations. Considerable effort was devoted to design analysis of individual water systems and components to develop recommendations for overcoming some of these limitations. Intermediate storage appears to be a method by which many farmers could economically improve their water supply systems to meet the high peak demands of the modern farmstead. It could also be a factor in keeping farmers from being forced to depend on surface sources for their water. A plan for a farmstead water system incorporating this feature has been prepared for the Cooperative Farm Building Plan Exchange.

A flow switch for controlling flow of water in a hose-nozzle-booster pump arrangement used in flushing livestock premises was devised and tested with promising results. On a swine farm its use reduced daily cleaning labor requirement by one-half and flushing water requirement by one-third.

Preliminary calculations indicate that nearly all of the 1 1/2 to 2 gallons of water used in cooling each gallon of milk on many farms can be saved and re-used. On some dairy farms this represents the largest use of water outside of consumption by the animals.

A basic design improvement has been developed for the hydropneumatic tank and a patent application is pending.

2. Farmstead manure disposal. Laboratory and field studies are continuing in Maryland, in cooperation with the Maryland Agricultural Experiment Station, on the characteristics of animal manures that affect their handling and disposal and on developing design criteria for disposal lagoons. Laboratory work has shown that a potable, sanitary "water" can be produced from manure lagoon effluent by chemical disinfection. The process should be within the means of many farmers. Observation of soil sealing and sludge buildup rates in an operating hog manure lagoon in Maryland substantiated previous laboratory findings of 39 days sealing time in a "Manor" soil and 1 mm. per month sludge buildup. Preliminary investigation of the effects of irradiation of lagoon liquids with radio-isotopes indicated that it is apparently possible to sterilize the liquids with low-level radiation and that algae cells are rendered non-reproductive for varying periods.

The major portion of a manuscript for a publication on farm animal manure disposal was prepared.

#### E. Farmstead planning

1. Chore time standards. At St. Paul, Minnesota, cooperative studies with the Minnesota Agricultural Experiment Station to establish time standards for farmstead work elements and a complete Standard Data Time System for analyzing farm work operations have been concerned with a search for the proper methods to be used in establishing such standards. In the absence of a coordinating standard for many of the composite work elements of the type found in farmstead operations, work has been directed toward determining a procedure to be used in establishing basic time elements for a standard data system. Studies thus far indicate the following procedure:

1. Establish the specific routine to be used in performing the work element.
2. Use only experienced operators and as many as is feasible.
3. Have operators attempt to pace themselves in performing the work element.

4. Rate performance and adjust the time values on each observation.
5. Eliminate all extreme observations.
6. Establish time standard as the average for all operators.
7. Confirm the resulting standards with time-studies of the same operation on an actual farm operation if such is available.

The use of this procedure by all research workers attempting to establish standard data would result in comparable standards which could be used to analyze farmstead operations in all areas.

2. Farmstead model layout studies. At St. Paul, Minnesota, cooperative studies with the Minnesota Agricultural Experiment Station on the use of models as a method of analyzing farmstead arrangements for efficient operation have continued. Effort has been directed to augmenting the supply of models and to determining the principles and procedures to be followed in analyzing specific arrangement problems. Commercial sources of suitable scale models are very limited, so models of any new building or equipment innovations have to be handmade in the laboratory and shop as the need arises. Studies of the procedure to be followed for using models has been directed to the analysis of actual farm arrangement problems in an attempt to verify previous observations. A limited number of applications tend to show that the best procedure is to set up, for viewing by the ultimate user, two or three possible arrangement solutions. All related factors, including advantages and disadvantages of each arrangement to be considered, can then be pointed out to assist in making a selection of the most efficient arrangement. Photographs can then be taken to make a record of the arrangement selected and, with the scaled grid background, these photos can be enlarged and used as a basis for making working drawings when the actual facility is to be constructed.

3. Turkey feeder location. At St. Paul, Minnesota, a cooperative study with the Minnesota Agricultural Experiment Station has been set up to investigate factors which may influence the arrangement, number, and location of the feeding equipment and subsequently the labor requirement in caring for turkey broilers. In a turkey facility having feeders arranged according to best available recommendations, initial observations of feed use per feeder give indication that about 30 percent of the feeders are used very little. Also that the pattern of feeding concentration is not consistent but may change for no apparent reason. Exploratory investigations tend to show the possibility of some correlation between litter moisture content and feeder non-use in specific areas of the pen. This factor as well as others including ammonia production, air temperature and waterer location will be studied to determine their influence on the arrangement and number of feeders necessary. If the influencing factor can be determined and corrected a reduction in the recommendations for feeder numbers and location may decrease the amount of labor required for feeding as well as for servicing the feeding equipment.

4. Hay wafer handling. At Davis, California, some preliminary work was done on the handling and storage of "Cal-Cubes". Results have not reached a reportable stage.

F. Fallout protection

At Beltsville, Maryland, work continued on development of plans and guide materials for fallout protection structures to be included in the Cooperative Farm Building Plan Exchange. Eight typical plans were developed for protective structures for farm families, animals, and crops, as follows:

A conventional type stall dairy barn, with radiation protection provided in the stall area, milkroom and personnel quarters by earth-banked walls, heavy mow floors, location of silos, and use of stored feed and bedding as shielding.

Two free stall dairy barns for use with loose housing systems. Radiation protection is provided by earth-bank shielding around the building and by a wash-down system on the roof. This permits use of low-cost pole-type construction and light-weight metal roofing.

A bunker type shelter for beef cattle which features the economy of an earth cover overhead and on three sides. Baled hay stacked in one end provides shielding and feed for approximately two weeks. A pressure-treated wood structure supports the earth cover.

A dual-purpose underground family shelter--fruit and vegetable storage of cast concrete.

A conventional on-farm potato storage with a family shelter in the center bin.

A family shelter in a farmhouse basement. This can also be used for other purposes, such as a photographic dark room.

A family shelter designed to protect from fallout, initial radiation, heat, and shock wave in areas subjected to 10 lb./sq.in. overpressure (1,440 lb./sq.ft.). In such areas wind speed would reach 285 mph and everything combustible would burn.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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AREA NO. 11: ELECTROMAGNETIC AND ULTRASONIC ENERGY FOR  
INSECT CONTROL AND OTHER FARM USES

Problem. Electromagnetic radiation has many established farm uses but research indicates many other highly useful potential capabilities in farm production, such as killing insects harmful to stored grain without leaving residues. Annual losses in recent years due to insects in field crops stored on the farm approximate 200 million dollars. To minimize the use of possibly hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical pest control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy. Since there is zero tolerance of DDT in milk, there is need for an electrical or physical means of controlling flies in and around dairy barns and milk houses. There is need for detecting or removing insects in food processing plants, including fruit flies in tomato canning plants, and larvae of the cabbage looper and imported cabbage worm that may be clinging to spinach leaves when delivered to the processing plant. The promising results of a project to control tobacco hornworm with only three traps per square mile using ultraviolet radiation as the attractant in a newly designed blacklight insect trap has raised the question, "What other insects can be controlled without using chemicals?" Production of many crops is hampered by poor, slow, or non-uniform emergence of seedlings after the seed is planted. Some electrical treatments have been found to accelerate germination and seedling emergence. If emergence in the field can be speeded up and better uniformity obtained, weed control can be much more effective, with resulting increased efficiency in production of crops. Treatments also increase the percentage of germination for some seeds and would therefore enable the establishment of good stands with lower investments for seed. Further, uniform emergence tends toward more uniform maturation with increased practicality of once-over harvest programs.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research involving agricultural and electrical engineers and physicists working cooperatively with USDA entomologists and with the Experiment Stations of nine States. Electrical and physical methods for corn borer control are studied in Iowa, cotton insect control in Texas, with the project contributing to Regional Research Project S-37, Basic Factors Involved in Control of the Pink Bollworm. Electrical and physical methods of tobacco insect control are studied in North Carolina and Virginia, and vegetable insect control and light trap design in Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station. Fly control in dairy barns is studied at Beltsville, Maryland. Research on electromagnetic

energy for control of insects in stored grains and seeds is carried on in Nebraska and for conditioning seed to improve germination and emergence in Nebraska, Tennessee, and Washington.

Studies relating to potential use of radiofrequency (RF) energy for insect control and improvement of seed germination are in cooperation with the Departments of Agricultural Engineering, Entomology, and Agronomy at the Nebraska Agricultural Experiment Station. Cooperative help on some phases of studies was furnished by the Crops Research Division, ARS, the Asgrow Seed Company, Eastern States Farmers' Exchange, Inc., the Agricultural Engineering Departments of the University of Idaho and Texas A&M University, and others.

Studies on effects of electric glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee in cooperation with the Departments of Agricultural Engineering, Agronomy, and Nutrition of the Tennessee Agricultural Experiment Station and the Crops Research Division, ARS. At Pullman, Washington, effects of glow-discharge radiation on germination of seeds and early plant growth were studied in cooperation with the Washington Agricultural Experiment Station, Washington State University.

The Federal scientific effort devoted to Agricultural Engineering research in this area totals 11.1 professional man-years; of this number 2.7 are devoted to electric traps for insect survey, destruction and control, 1.3 to components and design of electric insect traps for survey and control, 2.0 to physical methods of fly control, 4.4 to radiofrequency treatment of grain and forage seed, and 0.7 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Several of the States are engaged in programs of basic and applied research on the possible use of some of the various forms of electrical and physical energies as a means for improvement of the potential capabilities in farm production.

Investigations in progress, many of which are cooperative with the Department, involved the evaluation of the use of radiofrequency energy for treatment of grains to destroy insect infestation and treatment of seeds to improve their germination characteristics; exploration of the feasibility of using ultrasonics and electric shock to control rats, mice and birds; studies of the possibilities for a major advancement in the technology of small particle depositions through the application of electrostatic, thermal or other inertial forces; and use of light sources of various wavelengths for attracting and collecting insects which infest many of our economic crops.

A total of 2.0 professional man-years effort is devoted to this work.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Electric Traps for Insect Survey, Destruction and Control1. Electric Traps for Vegetable Insects

Research on the use of light traps for controlling vegetable insects was continued at Lafayette, Indiana in cooperation with the Departments of Agricultural Engineering and Entomology of the Purdue University Agricultural Experiment Station. The work is partially supported by the Indiana Electric Association.

Experiments with garden plots were continued for the sixth consecutive season. Cucumbers and tomatoes were planted in sixteen 60-ft. by 60-ft. isolated plots. Twelve of the plots were equipped with one light trap. Three different types of light traps were included in the experiment. Four of the plots were not equipped with a light trap. The effectiveness of the traps and insecticide treatments was determined from plant damage, insect counts, and yields. Three different insecticide treatments were compared in the study namely, six applications of dieldrin at two-week intervals, the same six applications plus five additional weekly applications until time of flowering, and no insecticide.

Cucumber yield data showed that light traps operated throughout the season combined with limited insecticide applications afforded protection from striped and spotted cucumber beetles. The best protection was provided by fan-type traps equipped with 15-watt blacklight (BL) lamps. Next in order came the electrocutor-grid type traps equipped with 5 BL lamps and a 5 BL gravity type trap. Yield differences were significant for the three trap types and all provided highly significant protection compared to unlighted plots. Both types of insecticide applications were highly effective in increasing yields over unsprayed check plots, but yields for the two different insecticide treatments were not significantly different. In studies using two strips of cucumbers 60-ft. wide by 840-ft. long, light traps were not effective for controlling cucumber insect pests at distances greater than 125 feet from the traps.

Activity of striped and spotted cucumber beetles was studied in a free-flight laboratory under controlled environmental conditions. Earlier response findings for the striped cucumber beetle were verified. The spotted cucumber beetle was found to react similarly. Neither species was active at 60°F. while both fly and respond positively to blacklight or green stimuli at 70°F.

Tests using corn earworm adults in the free-flight laboratory indicate that attraction to an electrocutor grid, which used no lamps as attractants, was caused by pinpoint corona discharges or by electric arcing. Earworms flew as well at 52° as at 60° or 70°F. Data were taken during the late flight of earworms to determine the time of light to traps in environmental conditions as they exist in the field. During light flights earworms were collected

randomly during the early evening hours. During heavy flights the insects flew to the trap in greatest numbers from 11 p.m. to 5 a.m.

Twelve light traps with five 15-watt blacklight lamps each in a 16-acre field proved very effective in protecting tomatoes from the larvae of both the tomato and tobacco hornworms. The damage to foliage and fruit was negligible. The tomato fruitworm (*Heliothis zea*) had no opportunity to damage tomatoes, since the main flight of the adults did not occur until the last of September and early October.

Studies including vegetable insects will be continued and expanded to determine the feasibility of controlling tomato insects in commercial plantings.

The use of light traps as insect survey tools will be studied with emphasis on corn earworms and cereal leaf beetles. Trap designs will be evaluated in terms of catch effectiveness.

Added emphasis will be placed on studies of the basic responses of insects to electromagnetic radiation.

In cooperation with the Virginia Agricultural Experiment Station and the Virginia Truck Experiment Station, a fan-type insect trap was used to determine its effectiveness on the egg-laying habits of drosophila in a tomato field. Few fruit flies of the available population were trapped and no effect was noted on egg-laying patterns. During the previous year a significant number of flies were caught when a similar trap was operated at a tomato cannery. Limited work will be continued.

In the cooperative insect population control study with the Entomology research Division at Oxford, North Carolina, data collected on corn earworm moths indicated that the traps caused a definite reduction in the number of infested ears of corn up to a distance of 300 feet from the trap. A general depression of the population inside the 113-square-mile area was also noted. More work is anticipated on traps as related to this insect.

## 2. Electric Traps for Grain Insects

In cooperative work at Purdue University, studies in the controlled-environment, free-flight chamber showed that cereal leaf beetle adults reacted positively by approaching both green and blacklight stimuli. In field studies cereal leaf beetles were caught in traps having green and blacklight lamps. They were also captured in traps without a light attractant. Many more beetles were caught using green and blacklight lamps than with yellow, red, and daylight white lamps in the traps. Adult beetles were found to be active at night as well as in the daylight.

Light traps have been operated near Ames, Iowa for the past 11 years in cooperation with the European Corn Borer Investigations Laboratory and the Iowa Agricultural and Home Economics Experiment Station. Light trap catches

furnish information on the emergence and extent of infestations of European corn borers and other economic insects. The information thus gained can be used in the timing of insecticide applications.

A total of 8,994 corn borers were captured in the four traps operated in 1963, reflecting the relatively low infestation. Higher ratios of female to male corn borers were captured in the traps with fluorescent-lamp attractants. The insect traps will be operated again in 1964 with the same cooperators.

### 3. Electric Traps for Cotton Insects

Laboratory and field studies relating to the use of visible and near-ultraviolet energy for attracting and collecting various species of cotton insects were continued in 1963 at College Station, Texas. Studies were conducted in cooperation with the Texas Agricultural Experiment Station and the ARS Entomology Research Division Laboratories at College Station and Brownsville, Texas. The Physics Department, Texas A&M University, cooperated informally in certain phases of these studies. This project contributes to Regional Project S-37, "Basic Factors Involved in the Control of the Pink Bollworm".

In cooperation with entomologists of the Southwestern Cotton Insects Investigations, ENT, College Station, Texas, group response techniques and a Y-shaped test chamber were used to study intensity-wavelength relationships influencing phototactic responses of the boll weevil. No threshold irradiation energy level for induced responses to 365-mu stimuli was perceptible from 0 to 16 uu watts/cm<sup>2</sup>. Response increased gradually within this range, becoming significantly different from no-stimulus response at levels greater than 16 uu watts/cm<sup>2</sup>. The log energy level vs. response curve was approximately linear for levels greater than 16 uu watts/cm<sup>2</sup>. Tests at other wavelengths (365, 490, and 615 mu) and energy levels (8, 80, and 800 uu watts/cm<sup>2</sup>) indicated an experimental design using energy levels of 24, 160, and 800 uu watts/cm<sup>2</sup> and wavelengths at 25- to 50-mu intervals should provide data for plotting a true action spectrum of response. Action spectrum determinations are planned as the next phase of this work. Information obtained should be helpful in determining design parameters (quality and quantity) for lamps to be used as effective boll weevil attractants.

Work has continued in cooperation with biophysicists of the Physics Department, Texas A&M University, in developing techniques and equipment for determining spectral response characteristics of individual insects by use of the electroretinogram (ERG). Electronic and optical equipment have been assembled which permit the viewing and recording of electric signals induced in the eyes of cockroaches by radiant energy stimuli. ERG studies are planned for the boll weevil, bollworm, and budworm in order to evaluate ERG techniques as a means of predicting whole-body response of insects to radiant energy stimuli.

Further assistance has been provided Texas Agricultural Experiment Station entomologists in the development of optical and electronic equipment to be used in studies of photoperiodic control of diapause of the pink bollworm.

Five projectors for monochromatic irradiation of insect cultures have been constructed, and qualitative and quantitative measurements of spectral emission characteristics are partially completed.

A thermopile and a thermal irradiation standard lamp were used to calibrate a phototube used for measurements of irradiation energy levels. This calibration provides a basis for measurements in absolute energy units, thereby facilitating comparisons of energy levels used in laboratory and field studies.

Studies on the response and physiological effects of light on the boll weevil were conducted in cooperation with the Entomology Research Division of ARS at the Boll Weevil Research Laboratory, State College, Mississippi.

Equipment was installed and calibrated for use in measuring light intensity. Preliminary tests were conducted with a Y-shaped tunnel in attempts to standardize procedures and to eliminate variables such as the pre-exposure dark period, exposure time, and insect food. Conclusive results were not obtained because sufficient numbers of insects were not available for the study. Some work is planned for next year when laboratory-reared insects are expected to be available.

#### 4. Electric Traps for Tobacco Insects

Laboratory investigations continued in cooperation with the Virginia Agricultural Experiment Station, Blacksburg, Virginia, on spectral response of hornworm moths to radiant energy bands centered at 3129, 3341, 3654, 4047, 4358, 4916, 5461, and 5780 Angstroms. Environmental conditions were maintained at a temperature of 75°F. and a relative humidity of 75%. Cooperation of ARS entomologists, Tobacco Experiment Station, Oxford, North Carolina, in furnishing laboratory-reared insects made it possible to conduct a more complete experiment than in previous years. The responses of insects to energy bands in the ultraviolet spectrum were significantly better than the responses to bands in the visible region.

Field tests were conducted at the Chatham, Virginia Tobacco Experiment Station on the effectiveness of lamp orientation and variations in the spectral output of blacklight fluorescent lamps for attracting insects. The vertical placement of lamps in comparison to those placed horizontally on traps again was more effective. No appreciable difference in the attractiveness of the lamps due to variations in the spectral output of the lamps was noted.

The field investigation to determine the effectiveness of blacklight insect traps for population control of tobacco hornworms was continued near Oxford, North Carolina, in cooperation with the Entomology Research Division, ARS. The hornworm population was extremely light during the season. Results obtained during the second year of operation of 324 traps in the 113-square-mile area showed a reduction in the tobacco hornworm population of about 80 percent. The corresponding reduction during the 1962 season was about 50 percent. A marked increase in stalk cutting in the trapped area in the fall of 1962 to

prevent late season breeding of hornworms contributed to the improved control in 1963. A limited number of traps equipped with fans were operated in the area. These appeared to be more effective in general for trapping corn earworm and tobacco budworm moths. Variations in trap design, including attractant lamp wattage and location, influenced the results. Efforts will be made to increase the area covered by traps during the 1964 season and to intensify work on trap design.

#### B. Components and Design of Electric Insect Traps for Survey and Control

Survey entomologists in nine North Central States and several Northeastern States continued use of light traps for weekly survey reports on insects of economic importance. Use of special light traps for European chafer detection was continued by Plant Pest Control Division, ARS, and several new areas of infestation were located in New York and Connecticut. Trapping of brown-tailed moth and winter moth in New England was successful for the second season and plans are being made for control experiments using electrocutor-grid traps for brown-tailed moth next season.

A commercial survey trap design using ethyl acetate as a killing agent was successfully used for both port-of-entry detection and general surveys in the Northeast. Designs for a similar 6-watt trap were tested and use of a trial group of 6-watt traps operated from inverters is planned in 1964. Catches of these smaller traps have been determined by PPC to be adequate for both European chafer detection and general survey use where commercial power is not available.

Assistance was provided the Purdue Entomology Department in installing and operating traps in 10 counties in Indiana. Information from this survey system was used for survey reports and in designing a program to study corn earworm migration. Initial studies were made in Southern Michigan to determine the feasibility of using traps to survey for cereal leaf beetles. Further work will be necessary before definite conclusions can be drawn from these studies.

At College Station, Texas, a grain-type sample divider was checked for accuracy in dividing insect collections. This device reduced labor and time required for identifying and counting insects in survey trap collections. With 19 heterogeneous collections, each containing 32 to 95 bollworm, cabbage looper, or budworm moths, the number of each species was estimated within 5% by using a  $\frac{1}{2}$ -sample of each collection. Sample preparation will be studied to improve sampling accuracy of the divider.

Survey traps were operated at different locations in a study of nightly correlations of trap catches. Correlation coefficients of 0.90 and higher were obtained for total catch (weight basis) and individual species at the shortest trap separation distance (approximately 500 feet). The longest separation distance (approximately 2 miles) produced correlation coefficients of 0.80 and lower. These results indicate the possibility of using one survey trap of

known sampling accuracy for estimating insect populations within a large area.

A new survey trap which is lighter and more compact than previous models was compared with an old-style survey trap for effectiveness in collecting insects and for general operational features. The mean number of bollworm moths caught with the new-type trap was greater than the mean number caught with the old-type trap. The mean catches of cabbage loopers were not significantly different. However, the mean total catches with the old-type trap were larger. These results indicate that the new-type trap is selective for bollworm moths. Further studies will be made to verify the selectivity shown for bollworm moths. General design features of the trap proved to be satisfactory for survey applications.

Trials were continued in Indiana to study the effect of type of blacklight phosphors and killing agents of light trap catches. Trap effectiveness in the phosphor comparisons will be evaluated on the basis of the total number of insects collected and on the number and variety of orders and species of economic importance included in the collections. These catches are not yet identified and therefore the data have not been analyzed.

Heat, ethyl acetate, cyanide dust, and cyanide granules were tried as killing agents. Temperatures of 140°-160°F. killed insects, but not quickly enough to keep the specimens easily identifiable. Both cyanide dust and granules gave satisfactory kills. Results were inconclusive concerning the use of ethyl acetate.

A test was conducted in Texas to determine whether a cylindrical extension from the bottom of the collection funnel on insect survey traps is essential for retention of moths or proper functioning of the moisture removal system or both. No significant difference was found in the weights of the catches or numbers of bollworm and cabbage looper moths with or without the funnel extension. The funnel extension did not appear to be essential to the proper functioning of the moisture removal system. Elimination of the cylinder reduces the height of the survey trap and makes possible a stronger connection between the collection funnel and the collection can.

Two types of 15-watt blacklight fluorescent lamps were evaluated for effectiveness in collecting insects. Insect attraction to a 365-mu peak emission lamp (old-type phosphor) and a 350-mu peak emission lamp (Philip's phosphor) was not significantly different. These results indicate either type of lamp is suitable for use in electric insect traps.

Operation of two commercial insect traps, one designed for survey and the other for control purposes, permitted evaluation of certain trap components and trap design features. A collection can designed for use of liquid killing agents and size separation of insects by screen trays was found to have potential value for use in survey traps. A small suction fan was found to satisfactorily retain insects trapped, but did not obviously influence the numbers of insects trapped.

### C. Physical Methods for Fly Control

Physical methods for controlling flies around dairy barns are being investigated at Beltsville, Maryland, cooperatively with the Animal Husbandry and Entomology Research Divisions, ARS.

Tests of the effectiveness of various commercial lamps in attracting flies to electrocutor grids were conducted in outdoor cages. Face flies were the most effectively attracted of the three species tested. They responded to three different fluorescent lamps, daylight, blacklight BL, and blacklight BLB. This proved successful only with confined populations. Attempts to kill face flies around barns with similar traps were not successful. House flies also were attracted by the same types of lamps, the percentage of a confined population attracted usually being 40-65%. Light was less attractive to stable flies than to either face flies or house flies. Observations indicated that the blood feeding schedule prior to testing greatly affects their behavior.

Suitable procedures were developed for testing the reactions of face flies to monochromatic light in a Y-chamber. Initial trials indicate greatest attraction in the blacklight ultraviolet region with progressively reduced attraction at both longer and shorter wavelengths.

### D. Electromagnetic Radiation Equipment for Insect Control and Treatment of Seed and Plant Products

#### 1. Radiofrequency Treatment of Grain and Forage Seed

Earlier studies have shown that all developmental stages of several species of stored-grain insects can be controlled by exposing infested wheat to radiofrequency (RF) electric fields for a few seconds. Such treatment does not damage the germination of wheat if its moisture content is low enough for safe storage. Equipment was constructed this year to pulse modulate the RF oscillators in efforts to improve the efficiency of the method for insect control. Pulse modulation permitted use of much higher field intensities without voltage breakdown in wheat. In prior work with continuous oscillation, higher field intensities have been more effective in killing stored-grain insects. New studies with pulsed treatments indicate that treatments employing 10-millisecond pulses at high field intensities are more effective than 5-millisecond pulses at the same field intensity with comparable energy input to the grain. Further work will be required to assess the true value of pulse-modulated RF treatments.

Physiological studies on yellow mealworms revealed no differences in amino acids extracted from whole insect preparations of RF-treated and untreated mealworms. Treatment in the pupal stage, however, resulted in adults with deformed or missing legs due to some injury sustained by the pupae during RF exposure.

Samples of DuBois winter oats, stored for 3 years after RF treatments which were effective in breaking dormancy, germinated as well as untreated seed from the same lot stored under the same uncontrolled atmospheric conditions.

Work will be continued on insect control and seed treatment studies to further evaluate potential uses of RF energy, with emphasis on gaining basic information concerning parameters of RF exposures and explanation of effects of treatment.

Germination and field emergence tests of Range, Narragansett, and DuPuits alfalfa seed, treated with three different types of electrical treatment 1 year earlier, indicated no damage from proper treatment levels. Infrared, RF, and gas-plasma treatments were all equally effective in increasing germination and emergence by reducing hard-seed percentages. Seed treated with continuous and pulsed RF exposures showed the same response to treatment in germination and greenhouse and emergence tests. After 3 years in uncontrolled storage, germination of several small-seeded legumes indicated no damage due to RF exposures of proper levels. Significant reduction of hard seed due to treatment was still evident in red clover, but germination of untreated alfalfa seed had increased to equal that of treated samples due to natural lowering of hard-seed percentage on storage. Germination tests on other alfalfa seed lots held in controlled storage for 3 to 5 years following RF treatment showed that hard-seed percentages were still substantially lower in RF-treated seed. This was verified in field tests by higher emergence in treated samples.

Infrared, RF, and gas-plasma treatments were also compared this year on sweet-clover seed lots with high hard-seed contents. All three types of treatment substantially increased germination and emergence of sweetclover seed treated at three different moisture contents.

Slight improvements in germination were achieved by RF treatment of green needlegrass and Lehman lovegrass seed. While increases were statistically significant, germination was still quite low.

Studies will be continued to evaluate effectiveness of RF energy, and probably infrared energy, for improving germination and emergence characteristics of seed. Efforts will be made to learn the basic reasons for observed effects of RF seed treatment.

Tests on alfalfa seeds which had received radiofrequency, infrared, and glow-discharge electrical treatments showed that the beneficial effect on germination and the increased rate of water uptake were still retained after 14 months in storage. Results of adverse-condition germination tests conducted by the Research Service Department of Northrup, King & Co. gave an indication that the electrically treated seed is no more susceptible to attack by fungi than is untreated seed.

Tests were conducted in cooperation with the University of Tennessee Department of Agronomy on glow-discharge seed treatment of crimson clover and

sericea lespedeza. Treatment produced significant increases in the germination of both hulled and unhulled sericea lespedeza. These tests are to be continued.

Results of a cooperative experiment comparing the effects of RF, infrared, and glow-discharge electrical treatments on sweetclover seeds indicate that all three treatments are about equally effective in reducing the hard-seed percentage and increasing the water sorption. Germination tests at Pullman, Washington revealed that all three treatments were more effective when the moisture content of the seed was reduced prior to treatment. The work on sweetclover will be continued with emphasis on determining the effect of seed moisture content on the results of the treatments.

Dormant Newport bluegrass irradiated in the electric glow-discharge at Pullman, Washington exhibited an increased germination rate. The moisture content of the seed at the time of treatment appeared to have no effect on the results and no significant difference in moisture sorption between treated and control samples was observed.

## 2. Radiofrequency Treatment of Vegetable Seed

Study of RF electrical treatment for improvement of vegetable seed germination was continued in cooperation with the Asgrow Seed Company Research Center, Twin Falls, Idaho. Accelerated germination of spinach seed discovered last year following RF treatment was noted again this year in one of two varieties tested.

RF treatment substantially increased germination in seed lots of garden peas and beans which contained hard seeds. Work will be continued on evaluation of RF treatments for improving vegetable seed germination.

## 3. Radiofrequency Treatment of Peanut Seed

Two lots of peanut seed were furnished by the Wilson County Peanut Co., San Antonio, Texas for RF electrical treatment. Results of this limited work appear promising since germination of one seed lot was increased from a low figure of 40 percent to 76 percent by RF treatment.

These studies may be expanded if suitable cooperative help will be available for testing germination of treated samples.

## 4. Radiofrequency Treatment of Tobacco Seed

Limited work on RF treatment of tobacco alkaloids to change chemical structure was continued in cooperation with the Crops Research Division, ARS. Additional evidence was obtained to indicate that RF treatment was effective in breaking down the ring structure of some alkaloids, where heat alone does not produce this result.

Earlier work with Crops Research Division treatment of tobacco seed with intense RF electric fields to produce genetic changes was prepared for publication.

Work on both of these studies is expected to be continued on a very limited basis.

##### 5. Radiofrequency and Glow-discharge Treatment of Cottonseed

Limited studies were continued on RF and glow-discharge treatment of cottonseed in cooperation with Texas A&M University. Some glow-discharge or gas-plasma treatments accelerated germination of Empire WR cottonseed, but no improvement was noted in field emergence tests. One RF-treated lot produced a significantly higher yield. Otherwise there was no change in staple or yield data. RF treatments also showed some promise in alleviating a hard-seed problem in cotton. Limited work will continue on cottonseed treatment research.

The range of the 60-cycles-per-second glow-discharge treatment was extended and under laboratory conditions increased beneficial effects on early emergence were noted for Empire WR fuzzy and machine-delinted cottonseed. A series of tests on seed treated in a glow-discharge energized at frequencies above 60 c.p.s. were carried out and resulted in improved earlier emergence as compared to untreated seeds. There were no significant differences due to frequency. Exploratory field plantings showed earlier emergence for seed treated at two of the new 60-c.p.s. treatments. A 3-year field test in cooperation with CR, ARS to investigate these new treatments will be started in 1964. A mechanically planted and harvested field test of treated cottonseed will be started in 1964 at the Tennessee Agricultural Field Station in Milan, Tennessee in cooperation with the Department of Agricultural Engineering.

Empire WR and Lankart seed was harvested from plants grown from treated seed of the previous year. These seeds were given the same treatments as the parent seed had received and were returned to the Texas A&M Experiment Station for planting.

Hard-seeded samples of an experimental cotton variety (16-B-7) developed by CR, ARS, Stoneville, Mississippi were treated and returned to Stoneville for evaluation. The best level of glow-discharge treatment produced an 81 percent germination on the sixth day after planting as compared to 9 percent for the control seed. Future developmental work on this variety is being transferred to Knoxville, Tennessee which will enable much closer cooperation between AE and CR.

##### 6. Glow-discharge Treatment of Soybeans

Laboratory tests at Knoxville, Tennessee with Lee, Hood, Hill, and Ogden soybeans revealed that certain levels of the glow-discharge treatment stimulated germination and radicle development, with the Lee variety being particularly benefited in early germination. Based on these findings a field test in cooperation with the Department of Agronomy is planned for 1964.

Analyses made by the University of Tennessee Department of Food Technology show that peroxide values of the ether soluble fraction of the treated soybeans oxidizes more rapidly than the untreated samples. Storage tests will be made on treated and untreated soybeans from the 1964 harvest.

Soybean meal was treated in a glow discharge for the Department of Nutrition. The treated meal used as the protein supplement of a diet proved to be unpalatable. The next experiment will be made with treated whole beans at a different level of treatment than used in 1962 when favorable indications of gain were noted.

#### 7. Glow-discharge Treatment of Dried Egg for Salmonella

Experiments were conducted at Pullman, Washington to determine the effectiveness of glow-discharge radiation in reducing the numbers of Salmonella in dried egg powder. Samples of diatomaceous earth (celite), dried egg albumen, and dried whole egg were inoculated with the bacteria and then irradiated. The results indicated complete destruction of Salmonella in the celite and a marked reduction in numbers in the albumen, but little, if any, reduction in numbers in the whole egg powder. The results of physical and chemical tests conducted on the irradiated egg product indicated that no appreciable amount of damage was done to the product. This work will be continued in cooperation with the Animal Science Department of Washington State University.

#### 8. Characteristics of the Electric Glow Discharge.

At Knoxville, Tennessee glow discharges were established by energy sources varied from 500 c.p.s. to 20,000 c.p.s. Some investigations indicate improvement in distribution of the effective areas of the discharge. Discharges at atmospheric pressure in some cases caused stimulation of germination of seed. These investigations will be continued. Effects of tube diameters on glow-discharge treatments were investigated. Indications are that current density is the limiting factor in tube diameter.

Additional temperature measurements were made at Pullman, Washington in the glow-discharge chamber using encapsulated chemical compounds of known melting point. A study of the effect of seed moisture content and treatment sample size on the temperatures in the chamber indicated that a particular temperature was reached sooner with smaller sized samples. For a given sample size the moisture content of the seed did not seem to have any measurable effect on the temperature obtained. For a given seed moisture content there appeared to be a direct relationship between hard-seed reduction in alfalfa and the temperature in the treatment chamber. This work will be continued with emphasis on refining the temperature measurement techniques.

A second continuous-treatment glow-discharge chamber was constructed. Preliminary tests indicate that this model will operate satisfactorily. It will be tested and modified as necessary.

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## AREA NO. 12: ELECTRIC EQUIPMENT FOR FARM LABOR REDUCTION

Problem. American agriculture produces about 600 million tons of crop and animal products each year. This is more than five times the weight of the total annual steel production in the United States. Most of these products are handled several times, which means a tremendous task of moving material. Development of equipment to decrease labor of livestock chores has been far less rapid than development of field equipment. For example, the production per man-hour for all crops increased nearly 400 percent in the last 50 years while the increase for poultry was only about 250 percent, for milk cows about 150 percent, and beef cattle less than 50 percent. The amount of working time spent on livestock production (estimated to be 3,833 million man-hours per year in 1961) now is 40 percent of the entire farm labor requirement. Equipment to substitute electric energy or tractor power for hand labor for many farmstead operations is now on the market but research is needed to provide flexibility of use in existing buildings and to permit automatic control as well as to extend mechanization to other operations. Because livestock chore equipment may be needed 365 days per year, it should pay for itself more quickly than field equipment which may be used only a few days per year. Increased emphasis on automatic materials handling equipment by livestock producers and equipment manufacturers has caused them to obtain advice and counsel of research workers. A continuing aggressive research program is essential to meet the developing needs of this segment of our national economy.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program with engineers working at Beltsville, and cooperatively with state experiment stations, USDA entomologists and other scientists on basic and applied research. Equipment and control for automatic feeding of livestock and poultry is under development in Washington and Illinois State Experiment Stations. Work on performance characteristics of upright-silo unloaders is in cooperation with the Minnesota State Experiment Station. Work on equipment for handling bees and honey is in cooperation with the Apiculture Branch, Entomology Research Division, and the Arizona and Wisconsin State Experiment Stations.

The Federal scientific effort devoted to research in this area totals 5.4 professional man-years; of this number 2.0 are devoted to bee equipment, 2.9 to equipment for livestock and poultry, and 0.5 to program leadership.

### PROGRAM OF STATE EXPERIMENT STATIONS

The agricultural experiment stations of many of the States have research underway whose major objectives involve the obtaining of information on the uses to be made of electrical energy to reduce labor, increase production and improve family living conditions. In the design of these studies provision

has been made to develop and investigate new equipment and explore the possibilities for new uses for electricity on the farm and in the home.

Many of the projects are concerned with the varied problems of chore labor mechanization and an expansion of the use of electricity for ventilating, heating, lighting and cooling under the various production enterprises of today's farming operations. Development and testing of prototype specialized equipment for product collection, processing, packaging, and transport, as well as crop storage, loading and unloading devices, are a part of the overall program of investigations.

Much of the research is conducted cooperatively with the Department.

A total of 9.7 professional man-years is devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Beef and Dairy Cattle Feeding Equipment

In Illinois, work cooperative with the University of Illinois Department of Agricultural Engineering has progressed on the automatic silo unloader control for dairy and beef cattle feeding systems. A 3-position (floating control) and 2-position control was tested at hoist speeds of 5-30 inches per minute. The 3-position control worked well at all hoist speeds. The 2-position control worked best at low hoist speed and with a current differential of .1 ampere or less. With a current differential of 1.0 ampere the discharge was erratic at all hoist speeds. The severity of variation increased as hoist speed increased.

In Minnesota the performance of electric motors for the operation of silo unloaders is being determined in cooperation with the University of Minnesota Agricultural Engineering Department.

An intensive electric motor testing program was continued during the past year. The requests for information in this area seem to be growing. The capacitor motors which the unloader industry discontinued six years ago were completely tested to give a base from which to predict required performances. Only one new repulsion-start induction-run motor was introduced during the past year while several capacitor motors were introduced. At the moment only two capacitor motors appear to have been redesigned to meet the requirements of this application. Several others are only reintroductions of general-capacitor motors of the type which proved to be unsatisfactory several years ago.

Upon completion of the laboratory tests, motors with questionable performance characteristics are placed in daily operation in a silo for six months.

Several motor manufacturers are now offering their new designs for testing under this project.

In a cooperative project with the Washington State University Agricultural Engineering Department the development of an automatic trench silo unloader has progressed. The unloader has a power requirement of 9-1/2 horsepower, operates in silos with irregular side walls, has the capacity of a vertical silo unloader and can be controlled manually or automatically. Under automatic control it cuts a 12-inch by 1-inch slice from the face of the silage at the rate of 100 pounds per minute. It can operate in all types of silage.

## B. Apiary Equipment

One project is located at Madison, Wisconsin. The Apiculture Research Branch, Entomology Research Division, is a joint participant and the Wisconsin Agricultural Experiment Station is a cooperator.

Conditioning equipment for extracted honey consisting of concentric tube heat exchangers, nylon strainers and a rotating drum cooler has given satisfactory performance. Adequate heat was available for pasteurization at measured flow rates up to 910 pounds per hour which was full pump capacity. Immediate cooling was accomplished with a concentric tube heat exchanger and drum cooler. The nylon cloth strainers are very effective for final straining and require little attention and a minimum of cleaning time.

Automatic operation of the can filling valve has been achieved by installing a solenoid of sufficient strength to compress the bellows when the valve is opened.

Extensive use of air furnished by a heavy duty vacuum cleaner for removing bees from filled honey supers has given very favorable results. Square supers, 6 5/8-inches deep, could be removed as quickly with air as with acid boards and were as free of bees. Temperature levels did not affect removal and bees were not irritated. Air supplied by an air compressor rated at 4.3 cfm and 35 psig was not effective. A squirrel cage blower using 2 hp. could not produce a sufficient velocity of air to remove the bees.

A definite preference for a coarse pore sponge used to supply water for bees was observed when two grades of synthetic sponge were used in a bee waterer. Addition of heat to the water supplied had no effect on preference nor did the location of the sponge in relation to the supply inlet. No surface temperature difference between the two types of sponge could be detected.

In a cooperative project with the Apiary Research Branch of the Entomology Research Division and the University of Arizona Agricultural Engineering Department, plastic combs made from dense polyethylene are being tested. In periods of low honey flow the bees tend to cap the cells below the plastic comb surface. This makes uncapping difficult. Cell size will be investigated next.

A pin-roller uncapper was patented in 1963. Forty-seven manufacturers and individuals have requested licenses and/or information to manufacture and describe the uncapping rollers.

White paint with linseed oil was proved best in hive paint durability tests.

A solar water collector developed by a Mr. Kobayaski of Japan did not work under Southwest U.S. desert conditions.

#### C. Hog Feeding Equipment

In Illinois the field tests of an auger feed injector were continued. The injector operated for a total of 1,951 hours and showed no signs of significant wear. A new model has recently been placed on test for a continuing study of performance.

Grooves in the injector auger casing did not increase performance. The through-put and the maximum operating head were reduced when conveying ground feed.

There have been 3 licenses issued to manufacturers to produce the auger feed injector for sale as part of a pneumatic feed conveying system.

#### D. Poultry Equipment

Studies involving a completely enclosed small automatic egg-sensing switch for automatically recording time of lay showed 327 perfect recorder marks of a possible 339 operations by a group of 20 switches. Three of the 12 errors were the result of switch malfunctions. The other nine resulted from eggs not tripping the switch, improper positioning of the switch or human error.

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### AREA NO. 13: ELECTRIC AND SOLAR EQUIPMENT FOR ENVIRONMENTAL CONTROL

Problem: Research has shown that temperature, light, space, and other environmental factors affect the growth, health, fertility, production, and feed consumption of farm animals. Thus, savings in feed, reduced losses from disease and exposure, and decreased costs of production may justify many environmental improvements. Special, controlled environments are necessary for the proper conditioning of crops like tobacco, sweet potatoes, grain, and peanuts; and are extremely effective in maintaining the quality of stored fruits and vegetables. Current scientific and economic developments indicate that production of vegetables and flowers in the future may require complete control of soil, light, and atmospheric conditions. Engineering problems associated with the application of light to plants have increased in recent years with the need for growth rooms for research and commercial use of light for growing crops. Conditioning and safe storage of high-moisture grain are major problems for a great many farmers. Use of solar heat to aid in drying offers potential economy in this operation. The lack of available electric energy in remote areas of a farm has limited the use of electric devices. Conversion of solar to electric energy at the site for adapting new and more efficient thermoelectric devices to farm application may eventually eliminate this energy shortage.

### USDA AND COOPERATIVE PROGRAM

A new program at Beltsville has been established whereby engineers from the Agricultural Engineering Division cooperate with the Crops Division on basic studies of light and thermal environment and their relation to plants in growth chambers. A continuing basic and applied program of solar energy collection and storage for grain drying and for supplementing heat energy to air-source heat pumps for house heating is underway in Kansas, in cooperation with Kansas State University. Solar energy collection and storage for direct house heating is also underway at Athens, Georgia, in cooperation with the Georgia Experiment Station. Research on equipment for basic and applied studies involving light and thermal environment for poultry is underway at Beltsville in cooperation with the Poultry Branch, Animal Husbandry Research Division. Basic and applied studies on the use of heat pumps to modify thermal environment for hog production were recently started at Holland, Virginia, in cooperation with the Virginia Agricultural Experiment Station.

The influence of electric equipment and environment on health and disease is being studied in USDA laboratories at Athens, Georgia. Equipment for the application of carbon dioxide to plants is under development at Pullman, Washington, in cooperation with the Departments of Agricultural Engineering and Horticulture of the Washington Agricultural Experiment Station. Studies on the performance of milk handling equipment are underway at Beltsville in cooperation with the Animal Husbandry Research Division and the Eastern Utilization Laboratory. Performance characteristics are being determined

for turf soil heating with electric cable at Purdue University in cooperation with the Departments of Agricultural Engineering and Agronomy of the Purdue Station. Performance characteristics of equipment are being studied for maintaining environment for conditioning potatoes for processing. This work is in cooperation with the Departments of Agricultural and Chemical Engineering, Horticulture and Plant Pathology of the University of Minnesota and the Market Quality Research Division and the Transportation and Facilities Research Division, ARS, East Grand Forks.

The Federal scientific effort devoted to research in this area totals 5.4 professional man-years; of this number 1.8 are devoted to plant environment equipment, 1.1 to solar equipment, 1.5 to poultry environment equipment, 0.2 to swine environment equipment, 0.3 to milk cooling equipment, and 0.5 to program leadership.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The State agricultural experiment stations are engaged in extensive basic and applied research to extend the advantages of controlled environment to all phases of agriculture in order to obtain maximum economic growth, production, product preservation and product quality. Studies of the possibilities for use of solar energy as well as electric energy to achieve the broad scale objectives are a part of the total program. Among the several investigations involved in these programs are determination of the effects that heat, light, space and other factors have on farm animals; soil, light and atmospheric conditions on plants; and temperature, humidity and gases on stored products. Special attention is being given to development of means for collection, storage and use of solar energy for structural heating and crop conditioning.

A great portion of this research is cooperative with the Department.

A total of 5.0 man-years is devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Equipment for Poultry Environmental Studies

At Beltsville, in cooperation with the Poultry Husbandry Branch, AHRD, this year's study completes the second year of a tentative 5-year program of orienting laying hens to an 18-hour diurnal environment where the temperature is maintained at 78°F. during the photoperiod and 62°F. during the dark period. Egg production during the 1962-63 study from the 60 highest layers was 3% (88% to 85%) lower than the highest 60 layers from the 24-hour control group. Results of the 1963-64 study show a difference of only 1.4% fewer eggs (86% to 84.6%).

During 1963-64, two studies of 144 Japanese Quail hens in each of the 18-hour and the 24-hour environments were completed. Egg production by Japanese Quail hens starts at 36-42 days of age, therefore, theoretically, three

studies of three 30-day laying cycles involving Japanese Quail can be completed during one cycle for chicken hens involving six 30-day laying periods. However, fertilization problems were encountered, thus reducing the season's work to one completed study. During this study the 18-hour quail hens laid 3.1% fewer eggs than their 24-hour controls. It is evident, also, from this study, that Japanese Quail are not stimulated to egg production by photoperiods shorter than 12 hours when placed in an 18-hour diurnally controlled environment of temperature and light.

Studies in cooperation with the Poultry Husbandry Research, AH Branch, of practical lighting systems for turkey breeding stocks have been completed. This year's work has been devoted entirely to preparation of publications describing and discussing the studies.

In Georgia, two trials were conducted in the altered air velocity facility to determine whether broilers 3 to 5 weeks of age would respond as favorably to increased air velocity as those 6 to 7 weeks of age had been found to do. Data obtained in these trials suggest that broilers as young as 3 weeks of age also grow faster and consume less water as the air speed in a hot humid environment is increased from 20 to 500 feet per minute. There were indications that air speeds higher than 500 feet per minute may reduce the growth rate and feed efficiency of broilers under 6 weeks of age.

Tests on the prototype environmental cabinet have indicated satisfactory performance of control systems for roof, wall, and floor temperatures and that further development is required to achieve satisfactory performance of control systems for air temperature and humidity.

#### B. Equipment for Swine Environmental Studies

Studies on swine environment in cooperation with the Virginia Agricultural Experiment Station on buildings and equipment for efficient swine production, including the utilization of heat pumps, has been continued in the environment temperature controlled building. The facilities have been modified since previous report by installing identical steel slotted floors in half of the environment temperature controlled building and in half of the semi-open house.

Specific Pathogen Free animals are now being used in this work. Because of the time required for converting to these animals, no summer test was made. The winter test was conducted with two lots of hogs on the slotted floor and two lots on concrete floor of each house. The floor space of 8.5 square feet per animal was maintained for all lots. This test included 15 more animals than in previous tests and the load on the heat pumps was reduced. Temperatures were adequately maintained with limited operation of heating equipment. The effect of the increased cooling load from this number of animals in summer has not been determined. Data from all tests are being analyzed for the preparation of a progress report. The experiment will be continued to include both summer and winter tests.

### C. Methods of Cooling Milk on Farms

Investigations were begun at Beltsville, Maryland to determine the effect on milk quality of varying the rate of cooling provided in mechanically refrigerated farm bulk milk tanks. Each trial consisted of the four successive milkings and intervening cooling and storage periods involved in an every-other-day milk pickup system. Milk samples collected before, during, and after each milking were analyzed for components of the microflora and for lipolysis. A simple aliquot sampling device was constructed to operate in conjunction with the pipeline vacuum releaser. Portions of each sample were pasteurized and evaluated by a flavor panel immediately and following eight days refrigeration. Control of the cooling rate in the ice-bank tank was accomplished by intermittent operation of the cooling water circulating pump according to a preset cycle. Milk temperature at fixed positions away from the tank walls at four levels was continuously recorded. Ambient and equipment temperatures, electrical quantities, and operations were continuously recorded.

From a series of experiments with an ice-bank tank it appears that when the quality of incoming milk is high (standard plate count of 10,000 to 40,000) the cooling rate can be decreased considerably below the maximum capacity of the refrigeration system without resulting in an increase in the microflora. The operating conditions leading to minimum detectable bacterial multiplication were found to exist between the two conditions when cooling water was circulated  $\frac{1}{2}$  minute of each 5-minute cycle and when circulated  $\frac{1}{2}$  minute in each 10-minute cycle. These two cycles cooled the first milking of the trial at rates of approximately 75 and 48 Btu/hr./gal. from the end of milking to 50°F. respectively. From the beginning of milking, the milk was cooled to 50°F. in about 4 and 6 hours. In the latter situation, the bacterial population rose to  $8 \times 10^6$  per ml by the end of the 48-hour period. In the range studied, changes in cooling rate did not affect either the flavor score of the milk or the acid degree value.

The relation between the temperature history of the milk and the bacterial growth rate was not constant. An initial lag, followed in the second cooling and storage period by temperature-dependent multiplication, was as expected. In the period following the third milking, however, there was an actual decrease in the bacterial population. The magnitude of this decrease varied directly with the population. During cooling and storage following the fourth milking, the bacterial population again increased at a temperature-dependent rate. This anomalous pattern of growth will be further investigated. The bulk tank studies will be extended to include direct expansion tanks, both atmospheric and vacuum. It will also be essential to study the influence of lower initial milk quality on the minimum acceptable cooling rate.

## D. Plant and Product Environmental Equipment

### 1. Carbon Dioxide Control in Greenhouses

The study of the engineering problems involved in the measurement and control of the carbon dioxide concentration in an air-supported plastic greenhouse was continued at Pullman, Washington, in cooperation with the Agricultural Engineering and Horticulture Departments of the Washington Agricultural Experiment Station, Washington State University.

The control system tested during the previous winter growing season was used throughout this report year. This control system allowed automatic control of the carbon dioxide concentration in four greenhouses at any constant level between atmospheric and 2,000 parts per million (ppm). Two new control systems have been built and some testing conducted. Both of these systems are designed to vary the carbon dioxide concentration with respect to the available light intensity. Crops of lettuce, radishes, stocks, carnations and okra were grown under controlled carbon dioxide concentration. The concentrations studied included atmospheric (about 300), 400, 800, 900, 1,200, 1,600, and 1,800 ppm. The yield (fresh weight of heads) of Bibb lettuce was doubled, or nearly doubled, when grown under increased carbon dioxide concentration of 900 and 1,800 ppm. Of equal significance was the observation that acceptable crops of lettuce could be produced at higher than optimum growing temperatures with increased carbon dioxide concentration. Radishes (Cherry Belle, White Icicle) exhibited a two- to four-fold increase in root weight and approximately a two-fold increase in root weight to top weight ratio. Stocks, a fast growing floral crop, produced a shorter, heavier, thicker stem, indicating a more rapid rate of carbohydrate accumulation. Carnations came into production approximately three weeks earlier, produced more total flowers and more flowers of a higher grade. Okra exhibited an increase in stem diameter, fresh weight, dry weight, leaf area, fresh weight per leaf area and dry weight per leaf area. For all of the crops and carbon dioxide concentrations studied during the year, production was increased, however, in some cases maximum production occurred at concentrations less than 1,800 ppm.

### 2. Plant Growth Equipment and Techniques

At Beltsville instrumentation is under development for use with a data logger for measuring humidity, light, air quality, air velocity and plant movement. In cooperation with Crops Research Division a far-red light source, a temperature gradient chamber, and a light-tight shutter for rapid light cycling were developed.

Experimentation continued through the year in a commercial growth chamber to determine effects of different lamps on the growth of beans. First experiments compared special commercial design fluorescent lamps to the standard cool white fluorescent lamps. After several experiments we found no increase in growth from the special lamps.

Experimentation then proceeded to compare fluorescent light alone and with incandescent light added. It was found that incandescent light definitely has an effect on increasing growth. The effect is complicated by other conditions such as ambient temperature, heating effect of incandescent light, the time after planting and duration of incandescent light. The greatest single effect so far determined occurs by having incandescent light on beans for four 16-hour periods with fluorescent light starting the 12th day after planting.

A commercial angle transducer has been adapted to measure plant growth, leaf movement, lateral stem movements or other plant movements. As small as .005 inch can be recorded on either a milliamp or milliwatt recorder. The signal can also be put into the data logger. Tests carried out with this sensor include growth and primary leaf and lateral stem movements of beans. Seedling growth of dark germinated and light treated zinnia seedlings was recorded for various light treatments. Indications are that there is a pause or even a shrinkage of plant growth when lights are suddenly turned on. Many applications of this can be foreseen as a rapid means of detecting plant response to various treatments.

### 3. Electric Equipment for Soil Warming and Plant Growth

Investigations were continued in Indiana to determine the fundamental requirements for installation and management of electric soil-heating cable systems to maintain suitable turf conditions for activities in critical-use areas during cold weather. This work is cooperative with the Purdue University Agricultural Experiment Station through the Agronomy and Agricultural Engineering Departments.

Research indicates that year-around use of turf areas is possible by applying supplemental heat to the rootzone of perennial turfgrass plants. Studies on a 20- by 60-foot plot installed in October 1962 with objectives to prevent soil freezing and maintain turf vitality without causing excessive blade growth have shown that soil thermostats installed just below the sod did not give adequate anticipation of changing weather conditions to keep the turf thawed at all times. Improved control systems are under study. There was little observed difference in soil or turf conditions above cables 4, 6 and 8 inches deep.

Turf areas warmed with electric soil-heating cables exhibited improved playability for sports events, increased root growth during the winter, extended growth period in the fall, earlier growth in the spring and, in some areas growth throughout the winter. Clear plastic ground surface coverings over warmed areas reduced the energy required, maintained greenness in leaf blades, reduced desiccation and favored growth. However, extra attention to remove and replace covers to avoid excessively high temperatures and disease buildup was necessary. Sods placed on heated areas developed new root extensions throughout the winter while sods on non-warmed areas developed no new roots.

Temperatures barely sufficient to keep rootzones thawed and porous did not produce obvious top growth until early March, 3 weeks ahead of unwarmed turf. Higher heat inputs to maintain 1-inch soil temperatures above 45°F. favored top growth in winter and late winter. Wattage densities of 10 watts per square foot were adequate to keep the turf unfrozen at all times. Soil temperatures above 55°F. forced growth even during extended severely cold weather.

Sharp drops to low temperatures caused some tip damage to leaf blades of growing bluegrass. Warmed turf areas produced seedheads 6 weeks earlier than unwarmed areas indicating crown growth through the winter period. After soil warming was stopped, all uncovered turf areas looked normal in density and uniformity. The warmed areas were never muddy, super-wet or slick from frost action.

Difficulties were encountered in snow melting because snow in the lower blade region of the turf would melt, leaving an air pocket with a crust of snow or ice supported on the tips of the blades. The rate of heat transfer through this region was reduced sufficiently to greatly slow additional snow melting.

Having narrowed the design parameters through preliminary work, 5 plots, each 10 by 120 feet, separated by 10 feet of unheated area, were installed in the Purdue varsity football practice field in August 1963. This 5-plot study will give information to allow more effective application of supplementary heat to turf using electric soil-heating cables with improved control systems.

#### 4. Environmental Equipment for Potato Conditioning

The quality of processed potatoes varies considerably depending upon potato varieties, cultural practices, growing conditions and environmental conditions in which the potatoes are stored. A study is in progress by other research workers to determine variety differences and the optimum storage conditions for each variety. Work in Minnesota is underway to determine the equipment requirements to produce the optimum storage environments. Four cold storage rooms are being used for the studies, two of them cooled by mechanical refrigeration. Initially a standard refrigeration unit was used. The 10° drop in air temperature upon passing through the evaporator coil resulted in frosting of the coil. This moisture originates from the potatoes and during a long storage period can reflect a considerable shrinkage loss. Experimental coils were then installed to reduce this moisture loss. The second coil with a large face area and one row of coils in place of four has been in operation during the present storage period. To provide the same quantity of cooling it was necessary to increase the air flow by  $2\frac{1}{2}$  times. There has been no frosting of the coil but the effect of the higher air velocity on the potatoes is being observed.

## E. Solar Equipment

### 1. Solar House Heating Equipment

For the fourth heating season a solar supplemented heat pump system is being investigated as a method of year-around air conditioning for a rural home. The effective area for the collection of solar energy is the same as it was last year (1962-63) or about 600 square feet. The vertical collectors face south and collect solar energy which is then accumulated as sensible heat in 50 cubic yards of crushed limestone in underground storage. The air-to-air heat pump then utilizes this stored heat as prescribed by preselected outdoor air and storage air temperature control settings. This work has been conducted cooperatively with the Kansas State Agricultural Experiment Station; Kansas State University's Department of Agricultural Engineering; the Kansas Power and Light Company, Topeka, Kansas and the Kansas Committee on the Relation of Electricity to Agriculture.

The data show a weighted average increase of 7.5 percent in performance factor during the 1963-64 heating season for the solar supplemented heat pump as compared with the heat pump which utilized outdoor air entirely as its heat source. The weighted average increase in performance factor for the 1962-63 heating season was about 14 percent. The smaller increase in performance factor for this past heating season (1963-64) can be attributed largely to the mildness of the winter weather.

A maximum increase of 26 percent in performance factor for a short test period was obtained for the solar supplemented heat pump as compared with the conventional heat pump. This is the largest increase in performance factor that has thus far been recorded during this field research program.

The nylon reinforced plastic fabric film on the solar collector has shown good weatherability. However recent spring wind storms have damaged three of the collector panels. The exact reason for this failure is not known at this time. However it appears that the deterioration of the wooden nailing strips which fasten the plastic cover to the collector frame was responsible in a large measure.

During the winter of 1962-63 at Athens, solar heating of a small test house indicated, by one method of analysis, that at 15° and 40° inside-outside air temperature differences the solar heat collected accounted for about 80 and 15 percent respectively of the total heat requirement. Malfunctioning of the modulating heat supply damper, discovered late in the season, may have had considerable influence on results. Other methods of analyses are being studied by Biometric Services. Additional data were taken during February and March 1964 as a check on the 1962-63 data, but the data compilation has not been completed. The separate collector-storage unit was designed for use where it would not be economical or feasible to remodel the house for most effective use of solar heat.

## 2. Solar Grain Drying Equipment

Solar supplemented grain drying tests were performed using newly developed collapsible plastic solar air heaters. The results of these tests showed close agreement on energy costs per bushel dried when compared with the 1962 tests. The 1962 fall grain drying tests used a fixed type solar air heater. Recorded data showed that about a 7°F. greater rise in air temperature was obtained with the new collapsible solar air heater as compared with previous systems. This was largely attributed to the manner in which the solar energy absorber was placed in the collapsible system. The placement of this absorber was such that the effective heat transfer area for the system was almost doubled while the total area of the collector remained the same.

### PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

#### Equipment for Poultry Environmental Studies

- Drury, L. N.; Brown, R. H. and Driggers, J. C. 1963. Performance of chick brooder types in uninsulated houses. Ga. Agr. Exp. Sta. Bull. N.S. 101. Apr. 32 pp.
- Marks, H. L. and Lucas, L. M. 1963. Time of oviposition under "short days". Poultry Science. Nov. 42(6):1466-1468.
- Marsden, S. J. and Lucas, L. M. 1964. Effect of short-day or low-intensity light treatments on reproduction of fall-hatched turkeys. Poultry Science. Mar. 43(2):434-441.

#### Plant and Product Environmental Equipment

##### Carbon Dioxide Control in Greenhouses

- Pettibone, C. A.; Matson, W. E. and Ackley, W. B. 1964. Control of carbon dioxide in an air-supported plastic greenhouse. ARS 42-92. Jan. 8 pp.

#### Solar Equipment

##### Solar House Heating Equipment

- Mowry, G. R. 1963. Solar energy collection and storage for a rural-home heat pump. Thirty-Ninth Annual Report of the Kansas Committee on the Relation of Electricity to Agriculture. May. pp. 41-52.
- Mowry, G. R. 1964. Solar energy supplemented rural-home heat pump. Solar Energy. Jan.-Mar. 8(1):12-16.
- Robertson, K. E. and Mowry, G. R. 1964. Solar heat supplements water heater. Sun at Work. First Quarter. 9(1):12-15.

Solar Grain Drying Equipment

Robertson, K. E. and Mowry, G. R. 1963. Solar heat aids grain drying. Sun at Work. Fourth Quarter. 8(4):3-5.

Robertson, K. E. and Mowry, G. R. 1963. Solar supplemented grain drying-fall 1963. Thirty-Ninth Annual Report of the Kansas Committee on the Relation of Electricity to Agriculture. May. pp. 36-40.

## AREA NO. 14: FARM ELECTRIC SERVICE AND INSTRUMENTATION

Problem: Farms east of the 100th meridian used twice as much electricity in 1959 as they did in 1950 and three times as much as they used in 1945. Increased use has forced many farmers to rewire or partially rewire their farmsteads at considerable cost. In some cases farm buildings are rewired unnecessarily to meet requirements of the National Electrical Code, which does not allow for diversity in the operation of farm loads. Overloading of installed wiring results in poor equipment performance, energy losses in the wiring, and creates a fire hazard. Transformers burn out or must be replaced due to overloading. There has been no good method of predicting when a transformer should be replaced and many power suppliers are faced with the problem of finding a simple, effective one. These problems are expected to become increasingly acute as farmers install additional electrical equipment such as house heating units, air conditioning, milk coolers, motors for feed processing and distribution, and irrigation pumps.

Today's technology in farming, as well as research, requires accurate instruments for measuring or monitoring processes such as grain and forage drying and plant and animal environment. Current agricultural research is especially dependent upon accurate instrumentation; some problems require completely new kinds of instruments. Studies are necessary to determine the accuracy and practicability of instruments for many kinds of agricultural measurements.

### USDA AND COOPERATIVE PROGRAM

The Department has a program involving agricultural and electrical engineers to develop an improved method of estimating the maximum electrical demands of farms. This program is in cooperation with the Iowa Experiment Station, the Rural Electrification Administration, and power suppliers in Iowa, Montana, Minnesota, North Dakota, Wisconsin, Kentucky, and Alabama. Data on energy consumption and electric equipment used on farmsteads are analyzed to predict electric demands by farms situated under similar conditions. Variations in electric equipment due to different crops, farming enterprises and weather require that studies also be made in other areas. Data obtained in cooperation with members of the Farm Wiring Committee of the American Society of Agricultural Engineers are analyzed in demand studies and in developing and substantiating changes to the National Electrical (N.E.) Code.

At Beltsville a program is underway to develop and provide accurate, practical and sometimes complex instrumentation for specific program needs.

Federal scientific effort devoted to research in this area totals 3.2 professional man-years. Of this number 1.2 is devoted to energy distribution and farm electric demand, 1.7 to instrumentation and 0.3 to program leadership.

## PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

The agricultural experiment stations of a few of the States have research investigations in progress studying the electric demands of farms and the major appliances used on farms in order to evaluate the effects of these demands on farmstead distribution systems. Exploration is also underway on the possibility of developing a safe distribution system for the farmstead using voltages which are higher than those currently allowed under the National Electrical Code.

Many of the studies are cooperative with the Department.

A total of 1.7 professional man-years effort is devoted to this work.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Energy Distribution and Demand

Studies of electric distribution systems requirements on farms are being conducted cooperatively with the Farm Wiring Committee of the American Society of Agricultural Engineers, the Edison Electric Institute, the National Rural Electric Cooperative Association and 113 power suppliers. Electric demands of 1055 buildings on 336 farms in 36 states were metered by power suppliers and analyzed by ARS. These data were used to prepare diversity factors and proposed code changes to the 1965 National Electrical Code. The present National Electrical Code does not allow any diversity in calculating feeder sizes serving farm buildings. The proposed code changes have been approved by two code-making panels of the Correlating Committee for the 1965 National Electrical Code.

In cooperation with engineers from the Rural Electrification Administration, a procedure based on multiple regression techniques is being developed for estimating required transformer sizes. A Kansas rural electric cooperative will present the favorable results of a field test of the procedure to the Institute of Electrical and Electronics Engineers (IEEE) Rural Electrification Conference in April 1964. In a study of the power factors of farms at the time of peak demands, it was found that farm power factors are higher than had been assumed. This finding will allow the more accurate conversion of kilowatt demands to kilovolt-ampere transformer sizes. Demand prediction equations for consumers with energy consumptions ranging from 0 to 600 kw.-hr. per month were investigated. Satisfactory prediction equations were developed for consumers with energy consumptions of 0 to 289 kw.-hr. Further investigation is required of the separation into energy consumption strata of consumers with low energy use. The data from the farms in the National Farmstead Wiring Study will be used in investigating the geographic extent to which present equations may be applied and in developing more reliable coefficients for demand estimating equations.

Physical facilities at the Minnesota research farm for distribution and use of 480 volts are not compatible with existing state safety rules for operating electric motors at 480 volts, consequently this project has not been active.

#### B. Research Instrumentation

Ultrasonic reflectance measurements were continued on hogs, cattle, and sheep for correlation with yields of meat cuts. Longissimus dorsi thickness of cattle and sheep were statistically combined with liveweight and compared with area and weight measurements from cattle and sheep. The multiple correlation of ultrasonic measures and liveweight were: with cattle Longissimus dorsi area, 0.35; with cattle weight yield of round, rump, and loin, 0.95; with sheep weight of trimmed or untrimmed leg, 0.95. Yield predictions, based on liveweight, were improved by adding the ultrasonic measures. A recently available bio-medical pulse-echo instrument was trial used and compared with existing unit. Some advantages were observed in respect to convenience; however, the operation principle is basically the same as presently used equipment.

#### PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

##### Energy Distribution and Demand

Altman, L. B. and Charity, L. F. 1963. Sizing distribution transformers for farms. Agricultural Engineering Journal. May. 44(5):240-245.

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl in	
			Summary of Progress	Area & Sub- Subheading
AEal	Weed, insect pest, & plant disease control machinery			
	Program leadership	Beltsville, Md.		
AEal-1 (Rev.#2)	Equipment for application of pesticides, defoliant, fertilizers and seeds from agricultural aircraft	Forest Grove,Ore.	Yes	3-G-1
AEal-4	Develop equipment and techniques for application of insecticides & fungicides to crops by ground machines	Wooster, Ohio Forest Grove,Ore.	Yes	3-F-1
AEal-6 (Rev.#2)	Aerial spray equipment for forest insect control	Beltsville, Md.	Yes	3-H-1
AEal-11 (Rev.)	Equipment for the application of chemicals to the soil for control of soil pests	Wooster, Ohio	Yes	3-B-1
AEal-12	Investigations of equipment and techniques for mechanical & chemical control of weeds in crops	Columbia, Mo. Ames, Iowa	Yes	3-D-1
AEal-14 (sup.AE c6-8)	Farm equipment requirements for improved corn production in the Southeast	Experiment,Ga.	No	
AEal-15 (sup. part AEc5-2)	Equipment for the above-ground application of agricultural chemicals in cotton	Auburn,Ala. Shafter,Calif. Lubbock,Tex. Stoneville,Miss.	Yes	3-E-1
AEal-16 (sup. part AEc5-2)	Equipment for soil incorporation of chemicals for cotton pest control	Stoneville, Miss. Shafter,Calif.	Yes	3-E-2
AEal-17	New mechanical and/or physical methods for insect control on grain crops.	Tifton, Ga.	Yes	3-C-2
AEal-18	Developing equipment for practical control of insects on grain crops grown in the Southeast	Tifton, Ga.	Yes	3-C-3
AEal-19	Detecting and measuring spray deposits on corn ears and silks	Tifton, Ga.	Yes	3-C-4
AEal-20	Mechanical methods of destroying fallen cotton squares	State College, Miss.	Yes	3-E-3
AEal-21	The development & evaluation of equipment and techniques for broadcast applications of granular pesticides with air blast machines	Wooster, Ohio	No	
AEal-22 (sup. AEal-3)	Evaluation of devices for distribution and metering of pre-emergence herbicides on the soil and mixed with the soil in the surface layer	Ames, Iowa & Columbia, Mo.	Yes	3-D-2
AEal-23 (sup. AEal-3)	The development and evaluation of equipment for control of corn insects in the Midwest	Wooster, O. & Ames,Iowa	Yes	3-C-1
AE-0-0-2 (DOD)	Equipment and techniques for applying herbicides to vegetation in Puerto Rico and Texas**	Mayaguez, Puerto Rico College Sta.Tex	Yes	3-I-1
Charter AEa2	Physics of Fine Particles,Pioneering Research Lab. Planting & fertilizing equipment & practices	Wooster, Ohio	Yes	3-A-1
	Program leadership	Beltsville, Md.		
AEa2-2 (Rev.)	Planting and fertilizing placement machinery for cultivated field crops & vegetable crops	Md.,Va.,Mich Ariz.,Wash,Nev.	Yes	2-A-1 2-D-1
AEa2-4 (Rev.)	Equipment for applying liquid fertilizer	Beltsville, Md. E. Lansing, Mich.	No	
AEa2-5 (Rev.)	Laboratory studies of the performance characteristics of seeding and fertilizer dispensing devices & equip.	Beltsville, Md.	No	

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			Summary of Progress	Area & Sub- Subheading
AEa2-8 (sup. AEa2-1rev.)	Equipment and practices for pasture and hay land establishment and maintenance	Beltsville, Md. Bushland, Tex. Athens, Ga.	Yes	2-B-1
AEa2-9	Development of equipment and techniques for cotton planting**	Shafter, Calif. Lubbock, Tex.	Yes	2-C-6
AE00-1	Equipment and methods for decontamination of agricultural lands affected by radioactive fallout	Beltsville, Md.	Yes	2-E-1
AEa3	Tillage machinery investigations			
	Program leadership	Beltsville, Md.		
AEa3-1 (Rev.)	Soil dynamics as a factor in tillage tool design	Auburn, Ala.	Yes	1-C-1
AEa3-2 (Rev.)	Basic studies of soil-working tools	Auburn, Ala.	Yes	1-D-1
AEa3-3 (Rev.)	Soil compaction by machinery	Auburn, Ala.	No	
AEa3-4 (Rev.)	Design and use of deep tillage implements	Auburn, Ala.	Yes	1-B-1
AEa3-5 (Rev.)	Effect of design factors on traction and transport equipment performance	Auburn, Ala.	Yes	1-A-1
AEa3-6 (Rev.)	Development of tillage machinery that will reduce soil erosion and runoff	Ames, Iowa	Yes	1-F-1
AEa3-7 (Rev.)	Measurement and characterization of physical properties of soil as related to tillage implements and tractive effort	Auburn, Ala.	No	
AEa3-8 (Rev.)	Mathematical relationships between forces and deformation in soil	Auburn, Ala.	Yes	1-E-1
AEa3-11	Equipment for transferring soil layers and improving surface soil characteristics	Stoneville, Miss.	Yes	2-C-4
E8-AE-1 (PL 480)	Tractive, stability and safety characteristics of wheeltypes farm tractor on steep slopes***	Helsinki, Finland	No	
A10-AE-2 (PL 480)	Tillage methods and implements for mountain farms	Jerusalem, Israel	Yes	1-G-1
E15-AE-1 (PL-480)	Development of methods and equipment for breaking up cohesive clay soils into small clod sizes up to a deep depth**	Bologna, Italy	Yes	1-G-2
AEb1	Farm housing	Beltsville, Md.		
AEb1-2 (Rev.#2)	Experimental farmhouses	Athens, Ga. Beltsville, Md.	Yes	8-C-
AEb1-3	The effect of selected construction and heat distribution means on environment, livability and climatic response in an expansible farmhouse	Beltsville, Md.	Yes	8-C
AEb1-5	Optimum attic fan arrangements for modern rural dwellings**	Athens, Ga.	Yes	8-C
AEb1-6	Effect of window and floor coverings on thermal environment in modern rural dwellings**	Athens, Ga.	Yes	8-A-1
AEb1-7	Effect of window and floor coverings on noise environment in modern rural dwellings**	Athens, Ga.	Yes	8-A-2
AEb2	Livestock shelters	Beltsville, Md.		
AEb2-1 (Rev.#2)	Determination of environmental design criteria for poultry house design	Beltsville, Md.	Yes	9-D-1
AEb2-2 (Rev.)	Environmental factors influencing development, production & health of dairy & beef animals under controlled conditions	Columbia, Mo.	Yes	9-A-2

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			Summary of Progress	Area & Sub- Subheading
AEb2-3 (Rev.)	Investigation of environmental factors influencing development, production and health of animals in warm climates	Davis, El Centro & Escalon, Calif.	Yes	9-B-1 9-C-1, 9-C-2 4, 5, 7, 8
AEb2-5	Reducing time and labor in caring for dairy animals through improved layout of buildings and yards, and the selection and adaptation of equipment	Davis, Calif.	Yes	9-A-1 10-E-4
AEb2-7 (Rev.)	Livestock shelters for southeast	Tifton, Ga.	Yes	9-C-3, E 9-A-2
AEb2-8	Evaluation & development of equipment & procedures for reducing chemical hazards associated with the control of livestock insects	Kerrville, Tex.	Yes	9-G
AEb2-9	Evaluation of radiant fluxes from the sky, ground & surroundings, & their influence on the radiant environment of livestock**	Davis & Columbia	Yes	9-F
AEb2-10	Use of models for analyzing farmstead layouts	St. Paul, Minn.	Yes	10-E-2
AEb2-11	Time standards for farmstead work elements	St. Paul, Minn.	Yes	10-E-1, 3
AEb2-13	Development of prototype environmental cabinet for poultry disease research	Athens, Ga.	Yes	9-D-2
AEb2-15	Environmental stress zones as criteria for design of heating, ventilating and air-conditioning equipment for turkey production	St. Paul, Minn.	Yes	9-D-4
AEb3	Storages & related equipment for farm products Program leadership	Beltsville, Md.		
AEb3-10 (Rev.)	Studies of basic factors in design & operation of silos	Beltsville, Md. E. Lansing, Mich.	Yes	7-A-1, 2, 3, 5
AEb3-11 (Rev.)	Development of improved methods, equip. & structures for making, storing & feeding silage in S.E.	Athens, Ga. Watkinsville, Ga.	Yes No	7-A-1, 4
AEb3-12	Farm storage of high moisture grain	Athens, Ga. Ames, Iowa	No Yes	7-A-6
AEb3-13	Silage and other forage density measurement with radioactive isotopes	Beltsville, Md.	Yes	7-A-1
AEb3-14 (Rev.)	Pressures of wheat & soybeans on bin walls, floors and structural members	Ames, Iowa	No	
AEb3-15	Structures and related equipment for control of plant environment	Beltsville, Md.	Yes	7-B-1
AEb4	Farm Building Plan exchange & information Program leadership	Beltsville, Md.		
AEb4-5 (Rev.)	Farmhouse plans & information	Beltsville, Md.	Yes	8-A-3, 8-D, 10-F
AEb4-6 (Rev.)	Farm service building plans and information	Beltsville, Md.	Yes	7-C, 9-A-3, 9-B-3, 10-B, 10-F
AEb5	Materials & construction methods for farm buildings Program leadership	Beltsville, Md.		
AEb5-4	Evaluation of stabilized earth blocks made under high pressure as a farm building material***	Beltsville, Md.	No	
AEb5-5	Development & evaluation of Portland cement-sand sandwich panels	Blacksburg, Va.	Yes	10-C-1
AEb5-6	Incorporation & application of hyperbolic paraboloid (HP) theory to the structural use of sheet materials in farm structure roof design	Beltsville, Md.	Yes	10-C-2
AEb5-7	Evaluation of rotational resistance of nailed joints to be used in farm structures	Blacksburg, Va.	Yes	10-C-3
AEb5-9	Influence of housing structures & equipment on airsacculitis & condemnations of broilers	State College, Miss.	Yes	9-D-3

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			Summary of Progress	Area & Sub- Subheading
AEb6	Farmstead water supply & wastes disposal Program leadership	Beltsville, Md.		
AEb6-2 (Rev.)	Farmstead water requirements	College Pk, Md.	Yes	10-D-1
AEb6-3	Characteristics of farm animal manures affecting design of disposal facilities**	College Pk, Md.	Yes	10-D-2
AEb6-4	Farm animal manure disposal lagoons**	College Pk, Md.	Yes	10-D-2
AEcl	Cotton ginning investigations Program Leadership	Beltsville, Md.		
AEcl-10	Gin waste collection and disposal***	Mesilla Pk. N.M. Stoneville, Miss. Clemson, S.C.	No	
AEcl-14	Measuring elements of fiber quality as affected by ginning & associated operations	Stoneville, Miss. Mesilla Pk., N.M. Clemson, S.C.	Yes	6-F-2
AEcl-15	Moisture contents of cotton for optimum gin house operation	Stoneville, Miss. Clemson, S. C.	Yes	6-B-1 6-G-1
AEcl-24	Fundamental mechanisms of nep formation in cotton	Mesilla Pk, N.M.	No	
AEcl-28	Reducing the degrading effects of weathering in the field & the action of insects & microorganisms on ginned cotton fiber & seed	Clemson, S.C.	Yes	6-C-2
AEcl-29	Investigations of the causes for changes in fiber properties resulting from conditioning treatments of cotton before cleaning & ginning	Stoneville, Miss.	Yes	6-F-2
AEcl-30	Investigation of fiber quality problems related to changes in production & harvesting practices as revealed thru ginning	Clemson, S.C. Stoneville, Miss. Mesilla Pk. N.M.	Yes	6-F-3
AEcl-31	Cotton ginning efficiency and cost	Stoneville, Miss. Clemson, S.C. Mesilla Pk., N.M.	Yes	6-F-1
AEcl-32	Development of alternative seed cotton cleaning devices and methods based on a thorough evaluation of present equipment	Stoneville, Miss Clemson, S.C.	Yes	6-C-1
AEcl-33	Improvement & evaluation of equipment for cleaning lint cotton	Stoneville, Miss.	Yes	6-G-1
AEcl-34	Improving cotton ginning performance through cotton quality evaluations and their relationships to ginning and associated operations	Mesilla Park, N.M.	Yes	6-F-3
AEcl-35	Improving extra long staple cotton ginning means and methods	Mesilla Pk, N.M.	Yes	6-E-2
AEcl-36	Roller gin adjustment for optimum performance	Mesilla Pk., N.M.	Yes	6-E-2
AEcl-37	Measurement of raw cotton length for cotton ginning evaluation	Stoneville, Miss. Mesilla Pk. N.M. Clemson, S.C.	No.	
AEcl-38	Gin stand research and development**	Stoneville, Miss.	Yes	6-E-1
AEcl-39	Materials handling and collection at cotton gins*	Stoneville, Miss. Mesilla Pk., N.M. Clemson, S.C.	Yes	6-A-1, 6-D-1 6-H-1, 6-I-1
AEc2	Long vegetable fiber engineering investigations Program leadership	Beltsville, Md.		
AEc2-2 (Rev.)	Improving processes & techniques for cleaning ramie ribbons	Belle Glade, Fla.	Yes	5-C-1
AEc2-7 (Rev.)	Developing harvesting & farm handling equipment for bamboo	Belle Glade, Fla.	Yes	4-F-1
AEc2-8 (Rev.)	Sansevieria harvesting, defibering, & fiber conditioning machinery & methods	Belle Glade, Fla.	Yes	4-F-2

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			Summary of Progress	Area & Sub- Subheading
AEc2-9 (Rev.)	Development of improved harvesting & processing machinery & methods for the production of kenaf and other jute like fibers	Belle Glade, Fla.	Yes	4-F-3
AEc3	Equipment for harvesting & farm handling of fruits and vegetables	Program leadership		
AEc3-9	Equipment & methods for harvesting apples***	Beltsville, Md. Wenatchee, Wash E.Lansing, Mich.	No	
AEc3-11	Equipment & methods for harvesting & farm handling and packing of cultivated blueberries***	E. Lansing, Mich.	No	
AEc3-12	Equipment & methods for harvesting cherries***	E. Lansing, Mich.	No	
AEc3-13 (Rev.)	Equipment & methods for handling & harvesting concord grapes	E. Lansing, Mich.	Yes	4-C-1
AEc3-14 (Rev.)	The effect of tillage & cultural practices on mechanized potato harvesting	E. Grand Forks, Minn.	Yes	1-B-2
AEc3-15	Equipment & methods for increasing the recovery of potatoes that are harvested mechanically***	E. Gr.Forks, Minn.	No	
AEc3-16	Equipment & methods for harvesting & orchard handling of prunes that are to be dried***	Davis, Calif	No	
AEc3-20	Equipment & methods for mech. harvesting cling-stone & freestone peaches & apricots	Davis, Calif.	Yes	4-C-2
AEc3-21	Mechanical injury of potatoes-evaluation, causes and prevention	E.Gr.Forks,Minn.	Yes	4-H-1
AEc3-22	Equipment & methods for thinning peaches & apples mechanically	E.Lansing, Mich.	Yes	4-C-3
AEc3-23	Engineering cost study of harv. potatoes mechanically	E.Gr.Forks,Minn.	No	
AEc3-24	Equip. & methods for harvesting dates mechanically	Davis, Calif	Yes	4-C-4
AEc3-25	Equipment and methods for harvesting and field handling citrus fruit	Lake Alfred, Fla. Davis, Calif.	Yes	4-A-1
AEc3-26	Mechanical aids and harvesting equipment & methods for picking apples for the fresh market**	Wenatchee, Wash. E.Lansing, Mich.	Yes	4-C-5
AEc3-27	Mechanized picking of apples and pears for processing outlets**	Wenatchee, Wash. E.Lansing, Mich.	Yes	4-C-6
AEc3-28	Development of equipment and methods for harvesting of apples & pears from trees of different sizes, shapes and planting distances**	Wenatchee, Wash. E. Lansing, Mich.	Yes	4-C-7
AEc3-29	Development of continuous-type self-propelled machine for harvesting cultivated blueberries**	E. Lansing, Mich.	Yes	4-C-8
AEc3-30	Equipment and methods for maintaining quality of cherries during mechanical harvesting & handling**	E. Lansing, Mich.	Yes	4-C-9
AEc3-31	Methods and equipment for harvesting prunes grown in the Coastal Region of California**	Davis, Calif.	Yes	4-C-10
AEc3-32	Bark damage to fruit trees resulting from mechanical shakers**	Davis, Calif. Lake Alfred, Fla. E. Lansing, Mich.	Yes	4-C-11
AEc3-33	Development of methods & equipment for multirow harvest of potatoes**	E. Gr.Forks,Minn.	Yes	4-H-2
AEc3-34	The development of equipment for application of dust to seed potatoes**	E.Gr.Forks,Minn.	Yes	4-H-3
AEc4- (Rev.)	Farm seed cleaning & handling	Program leadership		
AEc4-4	Seed cleaning research applied to specific problem mixtures	Beltsville, Md. Corvallis, Ore.	Yes	5-A-1
AEc4-6	Cutting & feeding mechanisms for legume & grass seed crop harvesting equipment	Clemson, S.C.	No	
AEc4-7	Improved techniques for harvesting seed crops	Corvallis, Ore.	Yes	4-E-1
AEc4-8	Development of a centrifugal-pneumatic seed separator	Corvallis, Ore.	Yes	5-A-2

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			Summary of Progress	Area & Sub- Subheading
AEc4-10	Optimum moisture content for seed harvesting	Corvallis, Ore.	Yes	4-E-2
AEc4-11	Modification of seed-length separators	Corvallis, Ore.	Yes	5-A-3
AEc4-12	Development of vibratory feeders for seeds	Corvallis, Ore.	Yes	5-A-4
AEc4-13	Development of a high-speed scalper for seed crops**	Corvallis, Ore.	No.	
AEc5	Equipment for mechanical cotton production			
	Program leadership	Beltsville, Md.		
AEc5-4	Equipment & techniques for crop residue disposal in cotton production	Stoneville, Miss.	Yes	2-C-1
AEc5-5	Equipment & methods for optimum seedbed preparation for cotton	Stoneville, Miss. Shafter, Calif.	Yes	2-C-2,5
AEc5-6	Power requirements of cotton production implements	Stoneville, Miss. Shafter, Calif.	Yes	2-C-3
AEc5-7	Synthetic mulches for improving cotton stands	Stoneville, Miss. Lubbock, Tex.	Yes	2-C-7
AEc5-8	Cooperative studies on the effects of production practices on the end use quality of cotton and cottonseed	Stoneville, Miss. Auburn, Ala. Lubbock, Texas Shafter, Calif.	Yes	4-B-1
AEc5-9 (Rev.)	Evaluation and development of cotton harvesting machines	Stoneville, Miss. Lubbock, Tex. Shafter, Calif.	Yes	4-B-2,3
AEc5-10	Reduction of moisture added to seed cotton by spindle-type harvesters	Stoneville, Miss. Shafter, Calif.	No	
AEc5-11	Sources of trash in cotton harvesting	Auburn, Ala. Stoneville, Miss.	Yes	4-B-4
AEc5-12	Plant characteristics affecting the performance of mechanical cotton harvesters	Auburn, Ala. Stoneville, Miss.	Yes	4-B-5
AEc5-13	Field separation of immature cotton bolls from mature cotton	Lubbock, Tex.	Yes	4-B-3
AEc5-14	Field handling and storage of machine-harvested cotton	Lubbock, Tex. Stoneville, Miss.	Yes	4-B-6
AEc6	Grain harvesting & conditioning Program leadership	Beltsville, Md.		
AEc6-10	Effects of heated air drying on grain quality	Ames, Iowa	No	
AEc6-11	Moisture relations in grains as they effect drier design	Ames, Iowa	Yes	5-D-1
AEc6-12 (Rev.)	Studies of the drying zone in mechanical grain driers	Ames, Iowa	Yes	5-D-2
AEc6-14	Mechanical damage to corn during harvesting & handling	Ames, Iowa	Yes	5-D-3
AEc6-15	Permissible time for drying grain using unheated air	Ames, Iowa	Yes	5-D-3
AEc7	Specialized crop production & harvesting machinery			
	Program leadership	Beltsville, Md.		
AEc7-8 (Rev.)	Development & improvement of peanut diggers and shakers	Holland, Va.	Yes	4-G-4
AEc7-9 (Rev.)	Development & improvement of tung harvesters & windrowers for optimum effectiveness & efficiency	Bogalusa, La.	Yes	4-G-2
AEc7-10 (Rev.)	Development & improvement of equipment & methods of handling tung fruit to storage on farm and to processing mill	Bogalusa, La.	No	
AEc7-11 (Rev.)	Farm processing of tung nuts	Bogalusa, La.	Yes	5-F-1
AEc7-13 (Rev.)	Development & improvement of peanut harvesting & field handling equipment	Holland, Va.	Yes	4-G-5
AEc7-14 (Rev.)	Development of improved harvesting, hulling & conveying equipment for castor beans and other oilseed crops	Stillwater, Okla.	Yes	4-G-1

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\*\*\* Discontinued during reporting year

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past year	Line Proj. Incl in	
			Summary of Progress	Area Sub-Heading
AEc7-15	Development of a cutter, cleaner, loader type of sugarcane harvester	Houma, La.	Yes	4-I-1
AEc7-16	Engineering studies of factors related to harvesting and farm processing coastal Bermudagrass	Tifton, Ga.	Yes	4-D-1 5-E-1
AEc7-17	Mechanical harvesting Burley tobacco	Lexington, Ky.	Yes	4-J-1
AEc7-18	Curing Burley tobacco	Lexington, Ky.	Yes	5-B-1
AEc7-19	Physical properties, forms, & treatments of forage	Beltsville, Md.	Yes	4-D-2 5-E-2
AEc7-20	Pruning of tung trees for facilitating the use of equipment in production & harvesting**	Bogalusa, La.	Yes	4-G-3
AEc7-21	Determine the engineering requirements for artificially conditioning castor beans for effectively hulling & maintenance of quality in storage**	Stillwater, Okla.	Yes	5-G-1
S3-AE-2 (PL-480)	Investigations in mechanization of sugarcane	Brazil	Yes	4-I-2
AEd2	Automatic electric controls for farm equipment Program leadership	Beltsville, Md.		
AEd2-1	Development of electric & other labor-saving & honey-conditioning equipment for apiary operation in North Central States	Madison, Wis.	Yes	12-B
AEd2-2	Development of electric & other labor-saving & honey-conditioning equip. for apiary manipulation in S.W.	Tucson, Ariz.	Yes	12-B
AEd2-5	Automatic electric control systems for livestock production	Urbana, Ill.	Yes	12-A-C
AEd2-6	Electric equipment for removing & handling silage from horizontal silos	Pullman, Wash.	Yes	12-A-
AEd3	Elec. equip. for environmental modification & control in farm living & production- Program leadership	Beltsville, Md.		
AEd3-2	Evaluation of electric equipment for reducing pig losses***	Lafayette, Ind.	No	
AEd3-3	Study of heat pump and solar energy for air-conditioning of farm homes & other farm buildings	Manhattan, Kan.	Yes	13-E-1,2
AEd3-5	Equipment systems for controlling light & temp. for turkey breeding stock	Beltsville, Md.	Yes	13-A
AEd3-7	Elec. equip. for efficient hog production (including heat pump for cooling & heating hog houses)	Holland, Va.	Yes	13-B
AEd3-8	Design factors for electrically controlled air flow and ventilation equipment in broiler houses	Athens, Ga.	No	13-A
AEd3-9	Relation & control of carbon dioxide & light & effects on plants in air supported plastic green houses	Pullman, Wash.	Yes	13-D-1
AEd3-10	Development of electric equipment to provide environmental control for investigations of sub-circadian periodicity in poultry	Beltsville, Md.	Yes	13-A
AEd3-11	Development of design criteria for lighting and other electrical equipment & controls for plant-growth environments**	Beltsville, Md.	Yes	13-D-2
AEd4	Application of electromagnetic radiation to plants, animals, & their products & to insects & soils Program leadership	Beltsville, Md.		
AEd4-1	Development of equipment for attracting & destroying economic insects with electric energy in North Central states	Lafayette, Ind.	Yes	11-A-1,2 11-B

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## Line Project Check List -- Reporting Year April 1, 1963 to March 31, 1964\*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl in	
			Summary of Progress	Area Sub- Subheading
AEd4-2	Use of radio frequency energy for insect control & conditioning of farm products	Lincoln, Neb.	Yes	11-D-2,3,4,5
AEd4-3	Developing of elec. equip. for attracting and/or destroying economic insects in the S.W. states	College Sta., Texas	Yes	11-A-3 11-B
AEd4-4	Development of electromagnetic radiation equipment for seed & plant product treatment	Knoxville, Tenn. Pullman, Wash	Yes	11-D-1,5,6 7,8
AEd4-5	Development of equip. for attracting, repelling and/or destroying economic insects with physical stimuli in southeastern states	Blacksburg, Va.	Yes	11-A-1,4
AEd4-6	Evaluation & development of equip. & physical methods for control of flies & other livestock pests	Beltsville, Md.	Yes	11-C
AEd4-7	The response and physiological effects of light on the boll weevil**	State College, Miss.	Yes	11-A-3
AEd5	Farm electric equipment performance & requirements & farm electric energy distribution Program leadership	Beltsville, Md.		
AEd5-1	Determination of electric demand characteristics of farm equipment	Ames, Iowa	Yes	14-A
AEd5-3	Electric milk cooling & handling equipment performance requirements	Beltsville, Md.	Yes	13-C
AEd5-4	Performance tests of unloaders for vertical silos	St. Paul, Minn.	Yes	12-A
AEd5-5	The use of 480 volts for distribution & use of electric energy for farm use	St. Paul, Minn.	Yes	14-A
AEd5-6	Evaluation of electric systems for soil warming**	Lafayette, Ind.	Yes	13-D-3
AEd5-7	Development of requirements & electric equipment for conditioning potatoes for processing**	E.Gr.Forks, Minn. St. Paul, Minn	Yes	13-D-4
AEd6	Development of technical instruments & measurement techniques for farm production & related electrification research Program leadership	Beltsville, Md.		
AEd6-1	Equipment for non-destructive measurement of fat and lean on live animals***	Beltsville, Md.	Yes	14-B

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